UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

MIDWEST ENERGY EMISSIONS CORP. AND MES INC., Plaintiffs, v, ARTHUR J. GALLAGHER & CO., *et al*., Defendants.	Civil Action No. 19-1334 (CJB)

OPENING EXPERT REPORT OF DR. STEPHEN NIKSA

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I. INTRODUCTION

1. My name is Stephen Niksa. I am the Founder and President of Niksa Energy Associates LLC, which provides consulting services to coal companies in the chemistry of solid fuel conversion and pollution control. I have been retained by Defendants AJG Iowa Refined Coal LLC, Arbor Fuels Company, LLC, Belle River Fuels Company, LLC, Canadys Refined Coal, LLC, Chouteau Fuels Company, LLC, Coronado Refined Coal, LLC, DTE Energy Resources, LLC, Erie Fuels Company, LLC, George Neal North Refined Coal, LLC, George Neal Refined Coal, LLC, Hastings Refined Coal, LLC, Huron Fuels Company, LLC, Jasper Fuels Company, LLC, Jefferies Refined Coal, LLC, Joppa Refined Coal LLC, Louisa Refined Coal, LLC, Newton RC, LLC, Portage Fuels Company, LLC, Superior Fuels Company 1, LLC, Walter Scott Refined Coal LLC, Williams Refined Coal, LLC, Bascobert (A) Holdings LLC, Buffington Partners LLC, CERT Operations II LLC, CERT Operations IV LLC, CERT Operations RCB LLC, CERT Operations V LLC, Cottbus Associates LLC, Larkwood Energy LLC, Marquis Industrial Company, LLC, Rutledge Products LLC, Senescense Energy Products LLC, and Springhill Resources LLC (collectively, "Defendants") as a technical expert in this litigation. In this report, I give my opinions regarding the invalidity of U.S. Patent Nos. 8,168,147 (Ex. 1001, "'147 Patent"), 10,343,114 (Ex. 2009, "'114 Patent"),

10,589,225 (Ex. 1097, "'225 patent"), 10,596,517 (Ex. 2002, "'517 patent"), and 10,668,430 (Ex. 2000, "'430 patent") (collectively, "Asserted Patents").

2. This declaration contains statements of my opinions formed to date and the bases and reasons for those opinions. I may offer additional opinions based on further review of materials in this case, including opinions and/or testimony of other expert witnesses.

3. In addition, should I be called to testify at trial, I may provide a tutorial regarding the materials I discuss in this and any future reports that I submit in this case, including all exhibits. This tutorial may include demonstratives such as computer graphics, videos, screenshots, and other presentation material regarding the asserted patents and the technology described therein. I reserve the right to rely on any of the references or documents cited herein in preparing demonstratives or other presentation materials regarding this technology or my opinions.

A. EDUCATION AND PROFESSIONAL EXPERIENCE

4. I have summarized in this section my educational background, career history, publications, and other relevant qualifications. My full curriculum vitae has been provided as Exhibit 1004 to this declaration.

5. I earned a Ph.D. in Chemical Engineering from Princeton University in 1982, and a B.S. in Chemical Engineering from Case Western Reserve University in 1975. I have over 40 years of experience researching coal combustion systems

and associated pollution control systems. Since 1997, I have been the Founder and President of Niksa Energy Associates LLC, which provides consulting services to coal companies in the chemistry of solid fuel conversion and pollution control. Prior to Niksa Energy Associates LLC, I worked at SRI International, taught at Stanford University, and worked at Sandia National Laboratories. My research interests have included chemical reaction mechanisms for NO_x, mercury, selenium, arsenic, phosphorous, and other trace metals, SO_3, volatile organic compounds (VOCs), particulates, alkali vapors, and polynuclear aromatic hydrocarbons (PAH); fuel conversion kinetics; transformation of alkali compounds in fuel combustion; and catalysis, including catalyst deactivation during hydrothermal treatment of residual petroleum fractions, and during flue gas cleaning in utility SCRs; predictive mechanisms for multipollutant (NO_x, SO_2, Hg^0) conversion across SCR catalysts; the thermal and chemical behavior of catalytic converters; and thermal shock issues in catalytic combustors for natural gas. I have authored hundreds of technical papers on the mechanisms of air pollutant formation and control. While at Stanford, I taught graduate courses in Radiation Heat Transfer; Combustion and Pollution; Physical Gas Dynamics; Introduction to Heat Transfer; Advanced Combustion; Analysis and Solution of Partial Differential Equations; and Spectroscopy Lab, FTIR Section.

6. Having this knowledge and experience, I am well-qualified to offer the opinions I express in this declaration.

B. COMPENSATION

7. I am being compensated at a rate of $315 per hour to reimburse me for my time spent working on issues in this case, which is my standard consulting rate, plus reimbursement of direct expenses. My compensation does not depend on the outcome of this matter or the opinions that I express. I have no financial interest in the outcome of this case.

C. MATERIALS AND OTHER INFORMATION CONSIDERED

8. I have considered information from various sources in forming my opinions. I have drawn on over five decades of research and development in this field. I have employed methods and analyses of a type reasonably relied upon by experts in my field in forming opinions or inferences on the subject. To make these determinations, I have relied on my experience and expertise, as well as my review of certain documents and discovery produced in this case. In preparing this report, I have relied upon the materials listed in **Exhibit 1**, as well as any other documents and information cited here.

D. PRIOR TESTIMONY

9. I was deposed in 2015 as an expert witness on a product warranty case involving SCR catalyst deactivation at a coal-fired power plant. In 2020 I was an expert witness on a two-patent challenge case involving Hg control by bromine addition and sorbent injection and drafted two 500-page expert reports. In 2014 and

2019 I was an expert consultant on patent infringement cases involving Hg control by bromine addition and sorbent injection.

II. THE CHALLENGED CLAIMS OF THE ASSERTED PATENTS

A. THE '147 PATENT

10. In this report, I address all the claims that have been asserted by Plaintiffs in the case. I reserve the right to analyze any additional claims that Plaintiffs might assert.

11. The Challenged Claims of the '147 Patent, which are claims 17-20 (and claim 1 from which they depend) are set forth below. Some of the claim elements have been further subdivided for ease of reference.

Claim Element	Claim Language from '147 Patent
1 (Preamble)	1. A method for separating mercury from a mercury containing gas comprising:
1(a)(1)	(a) promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter to form a promoted brominated sorbent,
1(a)(2)	wherein the bromine containing promoter is in gaseous form, vapor form, or non-aqueous liquid form,
1(a)(3)	and wherein the activated carbon contains graphene sheets having carbene species edge sites
1(a)(4)	which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury;
1(b)	(b) chemically reacting elemental mercury in the mercury containing gas with the promoted brominated sorbent to form a mercury/sorbent chemical composition; and

Claim Element	Claim Language from '147 Patent
1(c)	(c) separating particulates from the mercury containing gas, the particulates including ash and the mercury/sorbent chemical composition.
17(a)	17. A method according to claim 1, further comprising injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into a gas stream
17(b)	whereby in-flight reaction produces the promoted brominated sorbent,
17(c)	wherein the promoter is reacted in the gas phase or as a vapor,
17(d)	wherein the promoter is added at from about 1 to about 30 grams per 100 grams of the sorbent material.
18	18. A method according to claim 17, wherein the gas stream is a mercury containing gas.
19	19. A method according to claim 18, wherein the gas stream is a transport gas.
20	20. A method according to claim 17, wherein the promoter injection rate and the sorbent injection rate into the gas are determined at least in part on the monitored mercury content of the cleaned gas.

B. THE '114 PATENT

The Challenged Claims of the '114 Patent, which are claims 1-7, 12, 15, 16, 18, 20, and 23-30 are set forth below. Some of the claim elements have been further subdivided for ease of reference.

Claim Element	Claim Language from '114 Patent
l(Preamble)	1. A method of separating mercury from a mercury-containing gas, the method comprising:
1(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas,
1(b)	wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br, or a combination thereof,

Claim Element	Claim Language from '114 Patent
	wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br, or a combination thereof, or a combination thereof,
1(c)	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;
1(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;
1(e)	monitoring the mercury content of the cleaned gas; and
1(f)(1)	controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof,
l(f)(2)	so that the mercury content of the cleaned gas is maintained at or below a desired level.
2	2. The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas.
3	3. The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent.
4	4. The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material.
5	5. The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter.
6	6. The method of claim 1, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber.

Claim Element	Claim Language from '114 Patent
7	7. The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.
12	12. The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof.
15	15. The method of claim 1, wherein the combustion chamber comprises a boiler.
16	16. The method of claim 1, wherein the mercury-containing gas is a flue gas.
18	18. The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber.
20	20. The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof.
23(Preamble)	23. A method of separating mercury from a mercury-containing gas, the method comprising:
23(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas,
23(b)	wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2, HBr, Br, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br2, HBr, Br, or a combination thereof, or a combination thereof;
23(c)	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

Claim Element	Claim Language from '114 Patent
23(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.
24(Preamble)	24. A method of separating mercury from a mercury-containing gas, the method comprising:
24(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas,
24(b)	wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br, or a combination thereof, or a combination thereof;
24(c)	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;
24(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;
24(e)	monitoring the mercury content of the cleaned gas; and
24(f)(1)	controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof,
24(f)(2)	so that the mercury content of the cleaned gas is maintained at or below a desired level.

Claim Element	Claim Language from '114 Patent
25(Preamble)	25. A method of separating mercury from a mercury-containing gas, the method comprising:
25(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas,
25(b)	wherein the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof, or a combination thereof,
25(c)	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and
25(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.
26	26. The method of claim 25, wherein the coal comprises the added Br_2, HBr, the bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber.
27	27. The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof.
28	28. The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.

Claim Element	Claim Language from ’114 Patent
29	29. The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.
30	30. The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury.

C. THE ’225 PATENT

12. The Challenged Claims of the ’225 Patent, which are claims 1-2, 5-6, 8-9, 11-12, 14-15, 17-18, 20, 22-23, 25, 27-28 are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

Claim Element	Claim Language from ’225 Patent
1 (Preamble)	1. A method for treating a mercury-containing gas, the method comprising:
1b	combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and
1c	adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.
2	The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char.
5	The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas.
6a	The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and
6b	modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof.

Claim Element	Claim Language from ’225 Patent
8	The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof.
9	The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof.
11	The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof.
12	The method of claim 11, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof.
14a	A method for treating a mercury-containing gas, the method comprising:
14b	combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas;
14c	and adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.
15	The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char.
17a	A method for treating a mercury-containing gas, the method comprising:
17b	combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and
17c	adding a sorbent material comprising activated carbon into the mercury-containing gas.
18	The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof.
20	The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the

Claim Element	Claim Language from ’225 Patent
	HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility.
22	The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas.
23	The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas.
25	The method of claim 1, wherein the coal comprises subbituminous coal.
27	The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof.
28	The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof.

D. THE ’517 PATENT

13. The Challenged Claims of the ’517 Patent, which are claims 1-11, 13-15, 17-19, 21-26, 28-30 are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

Claim Element	Claim Language from ’517 Patent
1 (Preamble)	A method for reducing mercury in a mercury-containing gas, the method comprising:

Claim Element	Claim Language from ’517 Patent
1b	combusting coal in a combustion chamber, the coal comprising an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and
1c	collecting mercury in the mercury-containing gas with a sorbent added to the mercury-containing gas, the sorbent comprising activated carbon.
2	The method of claim 1, further comprising injecting an alkaline sorbent into the mercury-containing gas stream.
3	The method of claim 2, wherein the alkaline sorbent is selected from the group consisting of alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof.
4	The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof.
5	The method of claim 1, wherein the sorbent has a composition comprising from about 1 to about 30 grams of the element bromine per 100 grams of activated carbon.
6	The method of claim 1, comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas.
7	The method of claim 1, comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas with the sorbent.
8a	The method of claim 1, further comprising:
8b	measuring mercury content of the mercury-containing gas; and
8c	modifying, in response to the measured mercury content,
8d	an injection rate of injecting the sorbent comprising activated carbon into the mercury-containing gas,
8e	an amount of the additive comprising the Br_2, HBr, bromide compound, or a combination thereof, added to the coal, or
8f	a combination thereof.

Claim Element	Claim Language from ’517 Patent
9	The method of claim 8, wherein the measuring of the mercury content of the mercury-containing gas is performed substantially continuously.
10a	The method of claim 1, further comprising:
10b	modifying, in response to a measured mercury content,
10c	an injection rate of injecting the sorbent comprising activated carbon into the mercury-containing gas,
10d	an amount of the Br_2, HBr, bromide compound, or a combination thereof, added to the coal, or
10e	a combination thereof.
11	The method of claim 1, wherein the coal comprises a subbituminous coal.
13	The method of claim 1, wherein the coal comprises the added Br_2, HBr, the bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber.
14	The method of claim 1, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof.
15	The method of claim 1, wherein the coal is combusted in the combustion chamber at a coal-combustion facility, wherein the Br_2, HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the Br_2, HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility.
17	The method of claim 1, wherein the combustion chamber is an electric utility coal combustion chamber.
18a	The method of claim 1, further comprising:
18b	measuring mercury content of the mercury-containing gas; and

Claim Element	Claim Language from ’517 Patent
18c	modifying, in response to the measured mercury content, an injection rate of injecting the sorbent comprising activated carbon into the mercury-containing gas.
19	The method of claim 1, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.
21	The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the added Br_2, HBr, the bromide compound, or a combination thereof, per 100 g of the sorbent.
22	The method of claim 1, wherein the Br_2, HBr, or the bromide compound is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.
23	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is a sorbent obtained by contacting a base sorbent with a halogen or halide promoter prior to injection of the sorbent to the mercury-containing gas.
24	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is free of contact with a halogen or halide promoter prior to injection of the sorbent into the mercury-containing gas.
25	The method of claim 1, wherein the injection of the sorbent into the mercury-containing gas occurs upstream of a particulate separator or a scrubber.
26	The method of claim 25, wherein the particulate separator comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof.
29a	A method of separating mercury from a mercury-containing gas, the method comprising:

Claim Element	Claim Language from ’517 Patent
29b	combusting coal in a combustion chamber, wherein
29c	the coal comprises added Br_2, HBr, bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber, or
29d	the combustion chamber comprises added Br_2, HBr, bromide compound, or a combination thereof, or
29e	a combination thereof; and
29e	collecting mercury in the mercury-containing gas with a sorbent added to the mercury-containing gas, the sorbent comprising activated carbon.
30a	A method of separating mercury from a mercury-containing gas, the method comprising:
30b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein
30c	the coal comprises added Br_2, HBr, bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber, or
30d	the combustion chamber comprises added Br_2, HBr, bromide compound, or a combination thereof, or
30e	a combination thereof;
30f	collecting mercury in the mercury-containing gas with a sorbent added to the mercury-containing gas, the sorbent comprising activated carbon;

Claim Element	Claim Language from ’517 Patent
30g	separating the sorbent contacted with the mercury from the mercury-containing gas;
30h	measuring the mercury content of the mercury-containing gas; and
30i	modifying, in response to the measured mercury content of the mercury-containing gas,
30j	an injection rate of injecting the sorbent into the mercury-containing gas,
30k	an amount of the Br_2, HBr, bromide compound, or a combination thereof, added to the coal or the combustion chamber, or
30l	a combination thereof.

E. THE ’430 PATENT

14. The Challenged Claims of the ’430 Patent, which are claims 1-4, 6-8, 10-25, 28-29 are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

Claim Element	Claim Language from ’430 Patent
1 (Preamble)	A method of separating mercury from a mercury-containing gas, the method comprising:
1b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein
1c	the coal comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber, or

Claim Element	Claim Language from '430 Patent
1d	the combustion chamber comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof or
1e	a combination thereof;
1f	injecting a sorbent comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;
1g	contacting mercury in the mercury-containing gas with the sorbent; and
1h	separating the sorbent contacted with the mercury from the mercury-containing gas.
2	The method of claim 1, wherein the coal comprises the additive comprising the Br_2, HBr, the bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber.
3	The method of claim 1, wherein the combustion chamber comprises the additive comprising the Br_2, HBr, the bromide compound, or a combination thereof.
4	The method of claim 1, wherein the coal is combusted in the combustion chamber at a coal-combustion facility, wherein the additive comprising the Br_2, HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the additive comprising the Br_2, HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility.
6	The method of claim 1, wherein the combustion chamber is an electric utility coal combustion chamber.
7	The method of claim 1, wherein the combustion chamber is a coal combustion furnace.
8	The method of claim 1, wherein the coal comprises a subbituminous coal.
10a	The method of claim 1, further comprising

Claim Element	Claim Language from '430 Patent
10b	measuring the mercury content of the mercury-containing gas; and
10c	modifying, in response to the measured mercury content of the mercury-containing gas,
10d	an injection rate of injecting the sorbent into the mercury-containing gas,
10e	an amount of the Br_2, HBr, the bromide compound, or a combination thereof, added to the coal or the combustion chamber, or
10f	a combination thereof.
11	The method of claim 10, wherein the measuring of the mercury content comprises continuous measurement.
12a	The method of claim 1, further comprising:
12b	modifying, in response to a measured mercury content,
12c	an injection rate of injecting the sorbent into the mercury-containing gas,
12d	an amount of the Br_2, HBr, the bromide compound, or a combination thereof, added to the coal or the combustion chamber, or
12e	a combination thereof.
13	The method of claim 1, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.
14	The method of claim 1, wherein the sorbent contacted with the mercury comprises the element bromine and mercury.
15	The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas.

Claim Element	Claim Language from '430 Patent
16	The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas with the sorbent.
17	The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the added Br_2, HBr, the bromide compound, or a combination thereof, per 100 g of the sorbent.
18	The method of claim 1, wherein the Br_2, HBr, or the bromide compound is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.
19	The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof.
20	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is a sorbent obtained by contacting a sorbent with a halogen or halide promoter prior to the injection of the sorbent into the mercury-containing gas.
21	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is free of contact with a halogen or halide promoter prior to injection of the sorbent into the mercury-containing gas.
22	The method of claim 1, wherein the combustion chamber comprises a boiler.
23	The method of claim 1, wherein the mercury-containing gas is a flue gas.
24	The method of claim 1, wherein the injection of the sorbent into the mercury-containing gas occurs upstream of a particulate separator, a scrubber, or a combination thereof.
25	The method of claim 24, wherein the particulate separator comprises a baghouse, an electrostatic precipitator, a fabric filter, or a combination thereof.
28a	A method of separating mercury from a mercury-containing as, the method comprising:
28b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas

Claim Element	Claim Language from '430 Patent
	comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein
28c	the coal comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber, or
28d	the combustion chamber comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, or
28e	a combination thereof,
28f	injecting a sorbent comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;
28g	contacting mercury in the mercury-containing gas with the sorbent; and
28h	separating the sorbent contacted with the mercury from the mercury-containing gas.
29a	A method of separating mercury from a mercury-containing gas, the method comprising:
29b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein
29c	the coal comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber, or
29d	the combustion chamber comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, or
29e	a combination thereof;

Claim Element	Claim Language from '430 Patent
29f	injecting a sorbent comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;
29g	contacting mercury in the mercury-containing gas with the promoted sorbent;
29h	separating the promoted sorbent contacted with the mercury from the mercury-containing gas;
29i	measuring the mercury content of the mercury-containing gas; and
29j	modifying, in response to the measured mercury content,
29k	an injection rate of injecting the sorbent into the mercury-containing gas,
29l	an amount of the Br_2, HBr, the bromide compound, or a combination thereof, added to the coal or the combustion chamber, or
29m	a combination thereof.

III. TASK SUMMARY AND MATERIALS REVIEWED

15. I have been asked to review the Asserted Claims and its prosecution history, to provide an understanding of the technology relevant to the Asserted Claims, to review certain prior-art references, and analyze whether or not those references disclose or teach limitations of claims from the Asserted Patents. I have also been asked to review the Asserted Claims for compliance with 35 35 U.S.C.

112, and to opine on additional questions related to inequitable conduct and priority date considerations.

16. The opinions stated in this report are from the perspective of a Person of Skill in the Art (POSITA) as of August 30, 2004, whose qualifications and abilities are described below. I understand that Plaintiffs and Defendants may have a dispute as to whether the Asserted Claims are entitled to a priority date of August 2004, April 2009, or even a later date. Unless otherwise noted, my opinions expressed in this report remain unchanged regardless of the date used.

17. In forming my opinions, I have reviewed the Asserted Patents, their prosecution history, the materials cited in Exhibit 1 to the report, and the materials cited throughout my declaration. I have also relied on my academic and professional experience in reaching the opinions expressed in this declaration.

18. I have previously analyzed the validity '147 and '114 patents in connection with an *inter partes review* challenges to those patents.[1] My views on the validity of those patents has not changed in any substantive way, and I incorporate my declarations filed in those IPRs here as well.

IV. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE OF '114 PATENT

[1] *Inter Partes* Review No. IPR2020-00832; *Inter Partes* Review No. IPR2021-00834; *Inter Partes* Review No. IPR2021-00926; *Inter Partes* Review No. IPR2021-00928; *Inter Partes* Review No. IPR2021-01294; *Inter Partes* Review No. IPR2021-01295; *Inter Partes* Review No. IPR2021-01296; and *Inter Partes* Review No. IPR2021-01297.

A. INVALIDITY UNDER 35 U.S.C. § 102/103

19. The Asserted Claims of the '114 Patent are anticipated and/or would have been obvious to a person of ordinary skill in the art, based on the following grounds:

Ground	Claims Challenged	Prior Art	Based on Priority Date of
A	1-7, 12, 15, 16, 18, 20, and 23-30	Sjostrom in view of Eckberg	Apr. 2009
B	1-7, 12, 15, 16, 18, 20, and 23-30	Sjostrom in view of Olson-646	Apr. 2009
C	1-7, 12, 15, 16, 18, 20, and 23-30	Downs-Boiler	Aug. 2004
D	1-7, 12, 15, 16, 18, 20, and 23-30	Downs-Boiler in view of EPA-Proposal	Aug. 2004
E	1-7, 12, 15, 16, 18, 20, and 23-30	Downs-Boiler in view of Nelson	Aug. 2004
F	1-7, 12, 15, 16, 18, 20, and 23-30	Vosteen in view of Granite	Aug. 2004

B. INVALIDITY UNDER 35 U.S.C. § 112

20. The Asserted Claims of the '114 patent are invalid under 35 U.S.C. § 112 for lack of enablement and insufficient written description for the reasons I set forth in this report.

V. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE OF '225 PATENT

A. INVALIDITY UNDER 35 U.S.C. § 102/103

21. The Asserted Claims of the '225 Patent are anticipated and/or would have been obvious to a person of ordinary skill in the art, based on the following grounds:

Ground	Claims Challenged	Prior Art	Based on Priority Date of
G	1-2, 5-6, 8-9, 11-12, 14-15, 17-18, 20, 22-23, 25, 27-28	Sjostrom in view of Eckberg	Apr. 2009
H	1-2, 5-6, 8-9, 11-12, 14-15, 17-18, 20, 22-23, 25, 27-28	Downs-Boiler	Aug. 2004
I	1-2, 5-6, 8-9, 11-12, 14-15, 17-18, 20, 22-23, 25, 27-28	Downs-Boiler in view of EPA-Proposal	Aug. 2004
J	1-2, 5-6, 8-9, 11-12, 14-15, 17-18, 20, 22-23, 25, 27-28	Downs-Boiler in view of Nelson	Aug. 2004
K	1-2, 5-6, 8-9, 11-12, 14-15, 17-18, 20, 22-23, 25, 27-28	Sjostrom in view of Olson-646	Apr. 2009
L	1-2, 5-6, 8-9, 11-12, 14-15, 17-18, 20, 22-23, 25, 27-28	Vosteen in view of Granite	Aug. 2004

B. INVALIDITY UNDER 35 U.S.C. § 112

22. The Asserted Claims of the '225 patent are invalid under 35 U.S.C. § 112 for lack of enablement and insufficient written description for the reasons I set forth in this report.

VI. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE OF '147 PATENT

A. INVALIDITY UNDER 35 U.S.C. § 102/103

23. The Asserted Claims of the '147 Patent are anticipated and/or would have been obvious to a person of ordinary skill in the art, based on the following grounds:

Ground	Claims Challenged	Prior Art	Based on Priority Date of
M	17-20	Nelson in view of Olson-Paper and/or Lissianski-Patent	Aug. 2004
N	17-20	Downs-Halogenation in view of Olson-Paper	Aug. 2004
O	17-20	Lissianski-Presentation in view of Olson-646	Apr. 2009
P	17-20	Sjostrom in view of Olson-646	Apr. 2009
Q	17-20	Vosteen in view of Granite	Aug. 2004

B. INVALIDITY UNDER 35 U.S.C. § 112

24. The Asserted Claims of the '147 patent are invalid under 35 U.S.C. § 112 for lack of enablement and insufficient written description for the reasons I set forth in this report.

VII. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE OF '517 PATENT

A. INVALIDITY UNDER 35 U.S.C. § 102/103

25. The Asserted Claims of the '517 Patent are anticipated and/or would have been obvious to a person of ordinary skill in the art, based on the following grounds:

Ground	Claims Challenged	Prior Art	Based on Priority Date of
R	1-11, 13-15, 17-19, 21-26, 28-30	Sjostrom in view of Eckberg and/or Olson-646	Apr. 2009
S	1-11, 13-15, 17-19, 21-26, 28-30	Sjostrom in view of Olson-646	Apr. 2009
T	1-11, 13-15, 17-19, 21-26, 28-30	Downs-Boiler	Aug. 2004
U	1-11, 13-15, 17-19, 21-26, 28-30	Downs-Boiler in view of EPA-Proposal	Aug. 2004
V	1-11, 13-15, 17-19, 21-26, 28-30	Downs-Boiler in view of Nelson	Aug. 2004
W	1-11, 13-15, 17-19, 21-26, 28-30	Vosteen in view of Granite	Aug. 2004

B. INVALIDITY UNDER 35 U.S.C. § 112

26. The Asserted Claims of the ’517 patent are invalid under 35 U.S.C. § 112 for insufficient written description for the reasons I set forth in this report.

VIII. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE OF ’430 PATENT

A. INVALIDITY UNDER 35 U.S.C. § 102/103

27. The Asserted Claims of the ’430 Patent are anticipated and/or would have been obvious to a person of ordinary skill in the art, based on the following grounds:

Ground	Claims Challenged	Prior Art	Based on Priority Date of
X	1-4, 6-8, 10-25, and 28-29	Sjostrom in view of Eckberg	Apr. 2009
Y	1-4, 6-8, 10-25, and 28-29	Sjostrom in view of Olson-646	Apr. 2009
Z	1-4, 6-8, 10-25, and 28-29	Downs-Boiler	Aug. 2004
AA	1-4, 6-8, 10-25, and 28-29	Downs-Boiler in view of EPA-Proposal	Aug. 2004
AB	1-4, 6-8, 10-25, and 28-29	Downs-Boiler in view of Nelson	Aug. 2004
AC	1-4, 6-8, 10-25, and 28-29	Vosteen in view of Granite	Aug. 2004

B. INVALIDITY UNDER 35 U.S.C. § 112

28. The Asserted Claims of the '430 patent are invalid under 35 U.S.C. § 112 for insufficient written description for the reasons I set forth in this report.

IX. Additional Invalidity Opinions

29. It is my opinion that certain prior art references that I describe below were withheld from the US Patent Office by the inventors and their legal representatives were material to the validity of the Asserted Claims, were not duplicative of other information provided to the USPTO, and should have been provided to the USPTO during prosecution.

X. LEGAL STANDARDS

30. I am not a legal expert. In presenting my opinions, I have been informed of, and applied, the legal standards provided to me by counsel in arriving at the opinions set forth in this declaration.

31. I have been instructed that issued U.S. patents enjoy a presumption of validity and that invalidity of an issued patent claim must be proven by clear and convincing evidence. I have further been instructed that this standard means more than a "tipping of the scale" but less than "beyond a reasonable doubt."

A. LEVEL OF ORDINARY SKILL IN THE ART

32. When interpreting a patent, I understand that it is important to identify the relevant art pertaining to the patent-in-suit as well as the level of ordinary skill in that art at the time of the claimed invention. The "art" is the field of technology to which the patent is related.

33. I have been instructed by counsel that the person of ordinary skill in the art **("POSITA")** is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor's skill is not determinative of the level of ordinary skill. I further understand that the factors that may be considered in determining the level of skill include: the types of problems encountered in the art; prior art solutions to those problems; rapidity with which innovations are made; sophistication of the technology; and educational level of active workers in the field.

I understand that not all such factors may be present in every case, and one or more of them may predominate.

B. LEGAL STANDARD FOR PRIOR ART

34. I understand that a patent or other publication must first qualify as prior art before it can be used to invalidate a patent claim.

35. I understand that a U.S. or foreign patent qualifies as prior art to an asserted patent if the date of issuance of the patent is prior to the invention of the challenged patent. I further understand that a printed publication, such as a book or an article published in a magazine or conference proceeding, qualifies as prior art to an asserted patent if it was publicly available prior to the invention of the asserted patent.

36. I understand that a U.S. or foreign patent qualifies as prior art to an asserted patent if the date of issuance of the patent is more than one year before the filing date of the asserted patent. I further understand that a printed publication, such as a book or an article published in a magazine or conference proceeding, constitutes prior art to an asserted patent if the publication occurs more than one year before the filing date of the asserted patent.

37. I understand that a U.S. patent qualifies as prior art to the asserted patent if the application for that patent was filed in the United States before the invention of the asserted patent.

38. I understand that to qualify as prior art, a reference must contain an enabling disclosure that allows one of ordinary skill to practice the claims without undue experimentation. I understand that a patent issued by the United States Patent and Trademark Office is presumed to provide an enabling disclosure. I also understand that the full scope of a prior art reference need not be enabled; rather, it is only required that the portion related to the claimed invention be enabled. Factors to consider in determining whether undue experimentation is needed are the quantity of experimentation necessary, the amount of direction or guidance presented, the presence or absence of working examples, the nature of the invention, the state of the prior art, the relative skill of those in the art, the predictability or unpredictability of the art, and the breadth of the claims.

39. I understand that a U.S. patent qualifies as prior art to the asserted patent based on the date of filing a related provisional application before the invention of the asserted patent, so long as: at least one of the claims in the issued prior-art patent is supported by the written description of the provisional application; and the provisional application must also describe the subject matter relied upon in the issued U.S. patent.

C. LEGAL STANDARD FOR VALIDITY

40. I understand that for an invention claimed in a patent to be found patentable, it must be (among other things) new and not obvious based on what was known before the invention was made.

41. I understand that, once the claims of a patent have been properly construed, the second step in determining anticipation of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

42. I understand that prior art can "anticipate" the claims of an asserted patent. It is my understanding that in order for a claim to be anticipated by the prior art, every element of that claim must be found, explicitly or inherently, in a single prior art reference. In other words, to determine whether a single prior art reference anticipates a patent claim, one should consider not only what is expressly disclosed in that reference, but also what inherently occurred as a natural result of the practice of the system or method disclosed in that prior art reference.

43. It is further my understanding that to establish such inherency, the missing descriptive matter must be necessarily present in the item of prior art and that it would be so recognized by persons of ordinary skill in the art. It is also my understanding that such inherency may be shown through extrinsic evidence.

44. I understand that prior art can also render the claim "obvious" to a person of ordinary skill in the art. My understanding of this legal standard is set out below.

45. I have been instructed by counsel on the law regarding obviousness, and understand that even if a patent claim is not anticipated, it is still invalid if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time the invention was made to a person of ordinary skill in the pertinent art.

46. I have been informed and understand that the obviousness analysis requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

47. I understand that a person of ordinary skill in the art provides a reference point from which the prior art and claimed invention should be viewed. This reference point prevents a person of ordinary skill from using hindsight in deciding whether a claim is obvious.

48. I also understand that an obviousness determination includes the consideration of various factors such as (1) the scope and content of the prior art, (2) the differences between the prior art and the asserted claims, (3) the level of ordinary skill in the pertinent art, and (4) the existence of secondary considerations such as commercial success, long-felt but unresolved needs, failure of others, etc.

49. I am informed that secondary indicia of non-obviousness may include (1) a long felt but unmet need in the prior art that was satisfied by the invention of the patent; (2) commercial success or lack of commercial success of processes covered by the patent; (3) unexpected results achieved by the invention; (4) praise of the invention by others skilled in the art; (5) taking of licenses under the patent by others; and (6) deliberate copying of the invention. I also understand that there must be a relationship between any such secondary indicia and the invention. I further understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination. I also understand that secondary considerations are given less weight when the alleged invention represents a relatively small advance in a crowded field with predictable results.

50. I understand that an obviousness evaluation can be based on a combination of multiple prior art references. I understand that the prior art references themselves may provide a suggestion, motivation, or reason to combine, but other times the nexus linking two or more prior art references is simple common sense. I further understand that an obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace.

51. I understand that if a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill.

52. I also understand that practical and common-sense considerations should guide a proper obviousness analysis, because familiar items may have obvious uses beyond their primary purposes. I further understand that a person of ordinary skill in the art looking to overcome a problem will often be able to fit the teachings of multiple publications together like pieces of a puzzle, although the prior art need not be like two puzzle pieces that must fit perfectly together. I understand that an obviousness analysis therefore considers the inferences and creative steps that a person of ordinary skill in the art would employ under the circumstances.

53. I understand that a particular combination may be proven obvious by showing that it was obvious to try the combination. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp because the result is likely the product not of innovation but of ordinary skill and common sense.

54. I understand that the combination of familiar elements according to known methods may be proven obvious when it does no more than yield predictable

results. When a work is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or a different one. If a person of ordinary skill can implement a predictable variation, obviousness likely bars its patentability.

55. It is further my understanding that a proper obviousness analysis focuses on what was known or obvious to a person of ordinary skill in the art, not just the patentee. Accordingly, I understand that any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed.

56. I understand that a claim can be obvious in light of a single reference, without the need to combine references, if the elements of the claim that are not found explicitly or inherently in the reference can be supplied by the common sense of a POSITA.

57. I understand that a person of ordinary skill could have combined two pieces of prior art or substituted one prior art element for another if the substitution can be made with predictable results, even if the swapped-in element is different from the swapped-out element. In other words, the prior art need not be like two puzzle pieces that must fit together perfectly. The relevant question is whether prior art techniques are interoperable with respect to one another, such that that a person

of skill would view them as a design choice, or whether a person of skill could apply prior art techniques into a new combined system.

58. In sum, my understanding is that prior art teachings are properly combined where a person of ordinary skill in the art having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor, would have been led to make the combination of elements recited in the claims. Under this analysis, the prior art references themselves, or any need or problem known in the field of endeavor at the time of the invention, can provide a reason for combining the elements of multiple prior art references in the claimed manner.

D. LEGAL STANDARD FOR 35 U.S.C. §112

59. I understand a patent specification must contain a written description of the invention that it describes. I further understand that the written description may only be sufficient if it demonstrates that the inventor had possession of the invention at the time of filing. In other words, the specification must set forth the manner and process of making and using the claimed invention in full, clear, concise, and exact terms so as to enable any person skilled in the art to make and use the claimed invention.

E. LEGAL STANDARD FOR PRIORITY DATE

60. I understand that the "critical date" for a challenged patent is one year prior to its earliest effective filing date. It is my understanding that the critical date is significant because patents or other publications that are publicly accessible prior to the critical date, if they disclose each and every limitation of the claims, will invalidate a patent regardless of when the inventors invented the claim.

61. I further understand that, subject to the next paragraph, the asserted "priority date" of a patent is the earlier of: (a) the date on which a patent application is filed; or (b) the date on which an earlier-filed patent application is filed if the patentee claims the benefit of priority to that earlier-filed patent application. I further understand that the priority date is significant because patents or other publications that become publicly accessible less than one year prior to the priority date may invalidate the claims. My understanding is that, for such prior art references, a patentee may attempt to show that the claimed invention was conceived prior to the publication date of the prior art reference.

62. I understand that it is not enough for a patent to merely claim the benefit of an earlier-filed application, but that additional criteria must be met. In particular, the prior application itself must describe the claimed invention, and must do so in sufficient detail that one skilled in the art can clearly conclude that the inventor invented the claimed invention as of the filing date sought. First, I understand that

a priority-date analysis is on a claim-by-claim basis. Second, I understand that, in order for a patent claim to be entitled to the filing date of an earlier patent application, a "Section 112 analysis" must be conducted. A "Section 112" analysis, similar to what I describe above, encompasses looking to the earlier patent application, and ascertaining that earlier patent application meets both the written-description and enablement requirements as of the filing date of the earlier application. It is not enough that the claim would have been obvious from the earlier application, that application itself must describe the claimed invention.

63. I understand that in order to satisfy the written description requirement the earlier application must reasonably convey to those skilled in the art that the inventors had possession of the subject matter of the patent as of the filing date of the earlier application. I have been informed that it is the disclosures of the earlier patent application that counts, and that while the meaning of terms, phrases, or diagrams in the earlier patent application must be interpreted from the vantage point of one skilled in the art, all of the claimed limitations must appear in the specification. The descriptive means such as words, structures, figures, diagrams, formulas, etc. must fully set forth the claimed invention. In particular, all claimed limitations must be set forth in the specification. Further, I understand that this analysis is not a question of whether one skilled in the art might be able to construct the claimed invention from the teachings of the disclosure. The question is not

whether a claimed invention is an obvious variant of that which is disclosed in the specification; rather, an earlier application must itself describe each of the claim limitations.

64. I also understand that in order to satisfy the enablement requirement, the earlier application must enable a person of ordinary skill in the art to practice the claimed invention without undue experimentation.

65. I understand that a patent may be valid over prior art that was published or was publicly available before the priority date but after the critical date. To do so, it is my understanding that patentee must prove with corroborating evidence that the named inventors conceived of the claimed invention before the prior art and were diligent in reducing the claimed inventions to practice.

XI. PERSON OF ORDINARY SKILL IN THE ART

66. As described above, I have been provided the legal standards for determining the qualifications of a Person of Ordinary Skill in the Art ("POSITA").

67. As of the Asserted Patents' earliest claimed priority date (August 2004), a POSITA would have had at least a Master's Degree in chemical engineering, chemistry, or a related field of study, as well as knowledge of mercury chemistry—including knowledge of gas phase and heterogeneous reactions of mercury and halogen species at the temperatures and under the conditions found in coal-fired power plants. A POSITA would also have at least two years' experience with

research and development or implementing pollution control in power generation plants for natural gas, coal, and/or industrial waste incineration. Among other areas, the POSITA would have been familiar with each of the topics discussed below in the State of the Art section.

68. I understand that the parties may have a dispute as to whether the Asserted Claims are entitled to a priority date of August 2004 or as of April 2009. Either way, the qualifications of a POSITA, discussed above, would remain unchanged.

69. I was at least a person of ordinary skill as of August 2004, and I remain so.

XII. STATE OF THE ART

70. The Asserted Patents generally relate to "the removal of pollutants from flue gas or product gas from a gasification system."[2]

71. I understand that the Asserted Patents purport to trace ultimate priority to a provisional patent application that was filed on August 30, 2004. In the subsections below, I describe some basic principles of chemistry and engineering relating to coal combustion and removing pollutants (such as mercury) from gas streams. The principles discussed in the subsections below would have been well-known to a POSITA in August 2004 and earlier.

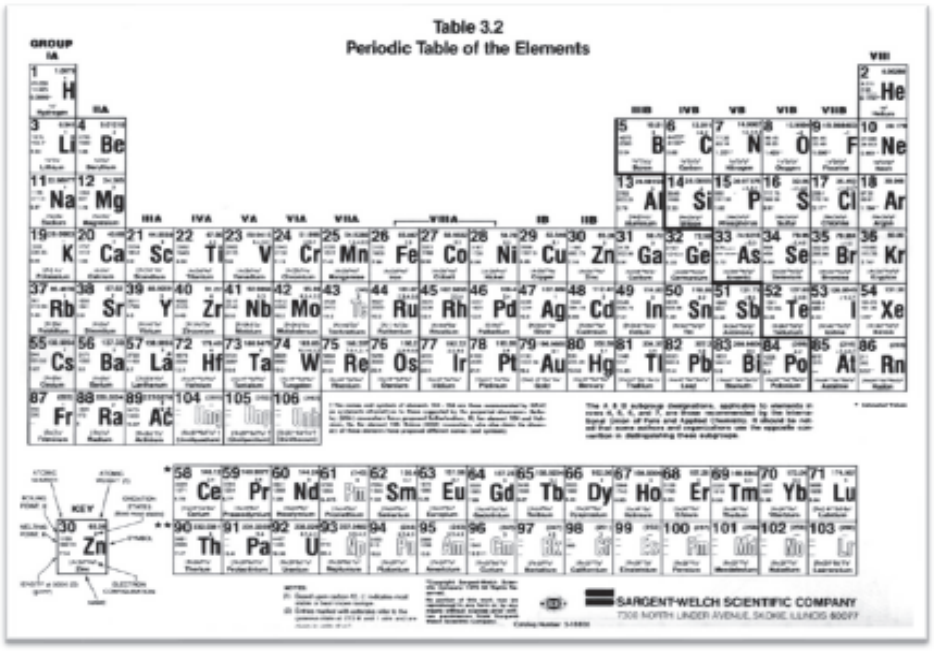
[2] Ex. 2009 ('114 Patent) at 1:28-29; Ex. 1001 ('147 Patent) at 1:29-31; Ex. 1097 ('225 Patent) at 1:30-31; Ex. 2002 ('517 Patent) at 1:45-46; Ex. 1099 ('430 Patent) at 1:41-42.

A. FUNDAMENTAL PRINCIPLES OF CHEMISTRY

1. Periodic Table and Chemical Notation

72. The periodic table of elements (or "periodic table" for short) is a common way to display chemical elements in a tabular manner. Each box in the periodic table represents a chemical element. The periodic table typically displays the atomic number and atomic mass of a chemical element, and some periodic tables display other properties. The atomic number refers to the number of protons in the nucleus of an atom. The atomic mass of a chemical element is the number of protons and neutrons in the nucleus of an atom, and is averaged to account for the occurrence of isotopes.

73. A sample periodic table from B&W: Steam is shown below:[3]



[3] Ex. 1027 (B&W: Steam) at exhibit page 239 (Table 3.2).

74. As can be seen above, the periodic table is arranged in periods (horizontal rows) and groups (vertical columns). It was well-known that chemical elements exhibit trends within a group.[4] Chemical elements within the same group tend to have similar chemical properties because they generally have the same electron configuration in their valence (outermost electron) shell. For example, both sodium (Na) and potassium (K) have one electron in their valence shell, while chlorine (Cl) and bromine (Br) have seven electrons in their valence shell.

2. Groups in the Periodic Table

75. As shown in the periodic table copied above, there are eighteen numbered columns (groups) of elements in the periodic table. Over the years, multiple conventions have developed in how the groups are numbered. The International Union of Pure and Applied Chemistry (IUPAC) labels the groups from Arabic numeral 1 through Arabic numeral 18. Group 1 is the left-most group (alkaline elements), and Group 18 is the right-most group (noble gas elements). An earlier group number system was also developed by the IUPAC, and another system was developed by the Chemical Abstracts Service (CAS), a division of the American Chemical Society. In the CAS and older-IUPAC numbering scheme, the numbers of the periodic groups represent the highest oxidation state of elements in the group. In the CAS numbering, an "A" designates a main-group element, and a "B"

[4] Ex. 1041 (Greenwood) at 27-29.

designates a transition-metal element. In the old-IUPAC numbering, an "A" designates an element in the left portion of the periodic table, and a "B" designates an element in the right portion of the periodic table.

3. Oxidation and Oxidation Number

76. An oxidation state, or oxidation number, is a fictitious charge assigned to atoms in a molecule that represent the law of conservation of charge; the oxidation numbers of atoms in a neutral molecule add up to zero, and the oxidation numbers in an ion add up to the charge on the ion. The oxidation number symbolizes the transfer of electrons from one atom to another in a molecule—a positive number represents loss of electrons, and a negative number represents the gain of electrons.[5] By way of example, oxidation numbers for a calcium ion would be represented as Ca^{2+} (because the calcium lost two electrons), and for a bromide ion would be Br^{-} (because the bromine gained an electron).

77. Oxidation refers to a chemical process by which an element is oxidized, or gives up electrons. Reduction refers to the chemical process by which an element is reduced, or accepts electrons. An oxidizing agent causes oxidation of another substance, while it itself is reduced.[6]

4. Group I (Alkali Elements), Group II (Alkaline Earth Elements), and Alkali Substances

[5] Ex. 1040 (Oxtoby) at 85.
[6] Ex. 1040 (Oxtoby) at 85, 87.

78. Common alkali components include salts from: (i) an alkali metal (Group I, typically sodium or potassium) or an alkaline earth metal (Group II, typically calcium or magnesium); and (ii) hydroxides (OH^-), carbonates (CO_3^{2-}), and phosphates (PO_4^{3-}). As such, common alkali components from hydroxides include: NaOH (sodium hydroxide, caustic soda, or lye); KOH (potassium hydroxide, potash or lye); $Ca(OH)_2$ (calcium hydroxide, lime); and $Mg(OH)_2$ (magnesium hydroxide). Common alkali components from carbonates include: $Ca(CO_3)_2$ (calcium carbonate, limestone) and $Mg(CO_3)_2$ (magnesium carbonate).

5. Group IV (Carbon)

79. Elements in Group IV of the periodic table include carbon (C), silicon (Si), and germanium (Ge), among others.

80. Carbon-based compounds are often represented by a shorthand formula, also referred to as a skeletal structure. Such representations of carbon-based molecules show a series of atoms bonded together, but do not typically label carbon and hydrogen atoms, as they are the most common elements in organic molecules. Such skeletal structures can depict chains, branches, and rings of carbon and other atoms bonded to one another. The following representations are common in skeletal structures:

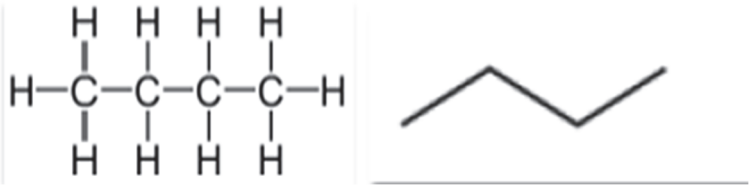
- A carbon atom is represented by a vertex, where two lines interact or terminate.
- Hydrogen atoms that are attached to carbons are not shown, as they are implied.

- A vertex without any labels represents a carbon atom bonded to other constituents and the number of hydrogens needed to satisfy the octet rule (i.e., eight electrons surrounding the carbon). Accordingly, a carbon bonded to four other carbons would not have any hydrogens.

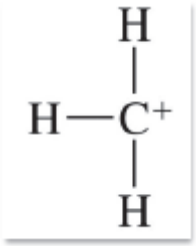
- A vertex labeled with a formal charge (e.g, + or -) indicates the number of valence electrons in an atom (4 for carbon) minus the sum of [(unshared electrons) + (number of bonds)].

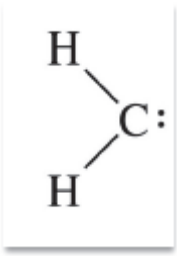
- A carbene carbon—a carbon without any formal charge but with two unshared electrons—is indicated by a ":" to represent the lone pair of electrons.

81. For example, two depictions of butane (C_4H_{10}) are shown below. A figure with all of the carbons and hydrogens labeled is shown on the left, and a skeletal structure of butane is shown on the right:



As another example, a carbocation with a formal charge of +1 is shown below to the left (with hydrogens shown for clarity), as it is a carbon surrounded by only 3 bonds. A carbene with a formal charge of 0 is shown below to the right, as it is a carbon surrounded by two bonds and one lone pair of electrons.





Exemplary carbene	Exemplary carbocation

82. In skeletal structures, certain common elements or groups of elements are indicated by shorthand. "X" represents a halogen atom or another ligand that donates only one electron (such as OH). "R" represents an alkyl or an organyl group (forming a carbon-carbon bond), such as CH_3CH_2—, $ClCH_2$—, $CH_3C(=O)$. Accordingly, carbene structures can be represented generically as H_2C: (methylene) or as R_2C: (generic carbene). The (:) indicates a lone pair of electrons.

6. Group V and Group VI Elements

83. Group V of the periodic table contains nitrogen (N), phosphorus (P), and other less common elements. Group VI contains oxygen (O), sulfur (S), and other less common elements. Oxygen is present by definition in all coal combustion systems.

7. Group VII Elements (Halogens)

84. "Halogen" refers to those elements of the periodic table in Group VII and includes the chemically related elements fluorine (F), chlorine (Cl), bromine (Br), and iodine (I).[7] Technically, astatine (At) with atomic number 85 is also a halogen, but it is radioactive and exceedingly rare in nature.

85. A summary of the four common halogens is provided below:

[7] Ex. 1040 (Oxtoby) at 788, 791, A.44.

	Fluorine (F)	Chlorine (Cl)	Bromine (Br)	Iodine (I)
Atomic Number	9	17	35	53
Atomic Mass	18.998	35.453	79.904	126.904

Some commonalities between the four above halogens are identified below:

- Each of the halogens exist as diatomic molecules in nature (e.g., F_2, Cl_2, Br_2, I_2)
- Each of the halogens are highly reactive due to their relatively high electronegativity. "Electronegativity is the power of an atom *in a molecule* to attract electrons to itself."[8]
- Each of the halogens have seven valence electrons in their outer electron shell.
- Each of the halogens act as oxidizing agents. They each raise the oxidation number of other elements that donate electrons.
- Each of the halogens form acids (referred to as hydrogen halides, or hydro-halides in short) when combined with hydrogen. When in aqueous solution, the hydrohalides become hydrohalic acids (e.g., hydrofluoric acid, hydrochloric acid, hydrobromic acid, and hydroiodic acid).

86. A "halide" or "halide compound" (e.g., chloride, bromide, iodide) refers to the compound that results when a halogen combines with another element. For example, table salt (sodium chloride, NaCl) is a chloride compound. An example of a bromide compound is calcium bromide, or $CaBr_2$.

[8] Ex. 1041 (Greenwood) at 25 (quoting Linus Pauling).

87. A "hydrogen halide" or "hydrohalide" refers to "the molecular species HX and also the pure (anhydrous) compounds as hydrogen halides" and their aqueous solutions are called "hydrohalic acids."[9] It was known that [a]nhydrous HX are versatile and vigorous reagents for the halogenation of metals."[10] Thus, hydrogen halides include hydrogen bromide (HBr), hydrogen chloride (HCl), and hydrogen iodide (HI).

8. Mercury

88. Elemental mercury (also referred to as metallic mercury) is a metal that may be found at ambient temperatures and atmospheric pressures as a heavy, silvery-white liquid.[11] The vapor pressure of mercury strongly depends on temperature, and mercury may readily vaporize at ambient conditions.[12] In general, atmospheric mercury is elemental mercury vapor.[13] Mercury metal may also exist in uncontaminated soil deposits at a concentration of from about 50 to about 500 ppb.[14] Additionally, mercury may be found as a sulfide in natural ore deposits.[15] Mercury

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[9] Ex. 1041 (Greenwood) p. 809.
[10] Ex. 1041 (Greenwood) p. 813.
[11] U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.
[12] U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.
[13] U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.
[14] *See* U.S. EPA, "Locating and Estimating Air Emissions from Sources of Mercury and Mercury Compounds," EPA-454/R-97-012 (Dec. 1997), available at https://www3.epa.gov/ttn/chief/le/mercury.pdf at 3-1.
[15] *See* U.S. EPA, "Locating and Estimating Air Emissions from Sources of Mercury and Mercury Compounds," EPA-454/R-97-012 (Dec. 1997), available at https://www3.epa.gov/ttn/chief/le/mercury.pdf at 3-1.

generally exists in three oxidation states: Hg^0 (metallic), Hg_2^{2+} (mercurous) and Hg^{2+} (mercuric).[16]

9. Common Units of Measurements

89. **Moles:** A "mole" is a unit in chemistry that relates the mass of chemical elements to macroscopic terms. A mole (abbreviated "mol") of a chemical substance is equal to 6.022×10^{23} atoms (or molecules) of that substance. So, for example, 1 mol of elemental bromine equals 6.022×10^{23} bromine atoms. The number of grams of an element is provided by the atomic mass of a substance. Accordingly, 1 mol of bromine atoms equals 79.904 grams, and 1 mol of bromine molecules (Br_2) equals 159.808 grams.

90. **PPM and PPB:** The parts-per notation has been used by engineers to describe small quantities, such as a mole fraction or a mass fraction. Common units in coal combustion are parts-per-million (ppm) and parts-per-billion (ppb).

91. **ACF and SCF**: ACF refers to "actual cubic feet," and is a measurement of the volume of a quantity (e.g., flue gas). SCF refers to "standard cubic feet," and is a measure of the volume of a quantity at a standardized pressure (typically 1 atm, which is also 101.325 kPa) and a standardized temperature (typically either 0°C or 25°C). MACF or MMACF refers to 1 million actual cubic

[16] Ex. 1060 at 2-1 (exhibit page 37); U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.

feet, and MSCF and MMSCF refers to 1 million standard cubic feet. The two quantities can be converted from one to another as follows:

$$SCF = ACF \times (P_{actual}/P_{standard}) \times (T_{standard}/T_{actual})$$

Absolute Hg concentrations can be expressed in μg/normal-m^3 @ 3%O_2.

B. COAL POWER PLANTS AND ASSOCIATED UNITS

1. Types of Coal

92. As of 1992 coal was the most common fossil fuel in use globally for utility and industrial power generation.[17] It was known that coal tends to be a heterogenous fuel source, meaning that its chemical composition may vary by location and even within a coal seam.[18] Thus, a system of classification of coal was standardized by the American Society of Testing and Materials (ASTM) that organizes the broad characteristics of coal by rank.[19] This classification system uses a given coal's heating value and quantities of volatile matter and fixed carbon content as ranking criteria based on proximate analysis. [20] The four classifications are organized from highest to lowest rank as: (I) Anthracitic; (II) Bituminous; (III) Subbituminous; and (IV) Lignitic.[21] It was known that, as a byproduct of combustion, some unburned carbon is present in the combustion and flue gases.

[17] *See* Ex. 1027 (B&W: Steam) at 8-1.
[18] *See* Ex. 1027 (B&W: Steam) at 8-3.
[19] *See* Ex. 1027 (B&W: Steam) at 8-4.
[20] *See* Ex. 1027 (B&W: Steam) at 8-4.
[21] *See* Ex. 1027 (B&W: Steam) at 8-5.

The amount of unburned carbon, often referred to as loss on ignition (LOI), was generally proportionally related to the rank of the coal being fired due to the higher volatility and faster burning rates of the lower rank coals. Therefore, there are typically proportionately lower amounts of unburned carbon in the flue gases of low-rank coals such as lignite and subbituminous coal.

93. The major organic components of coal include carbon, hydrogen, and oxygen.[22] Impurities in coal typically include sulfur, nitrogen, and ash. Such impurities, and others, can give rise to hazardous air pollutants (HAP), such as the pollutants of sulfur oxides (SO_x) and nitrogen oxides (NO_x) discussed below.[23] In 1998, the EPA published its final report to Congress based on a study of HAPs from electric utility steam generation in analyzing thirteen "priority HAPs."[24] Among the priority HAPs, the EPA report concluded that "[b]ased on available information and current analyses, the EPA believes that mercury from coal-fired utilities is the HAP of greatest potential concern."[25]

2. Combustion Chamber and Boiler

94. It was known that the main method in use by the electric utility steam generation industry for the combustion of coal as a fuel source was pulverized coal

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[22] *See* Ex. 1027 (B&W: Steam) at 8-3.
[23] *See* Ex. 1027 (B&W: Steam) at 8-3.
[24] *See* U.S. EPA, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generation Units -- Final Report to Congress," (Vol. 1 1998), available at https://www3.epa.gov/ttn/utox/eurtc1.pdf, at ES-5.
[25] U.S. EPA, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generation Units -- Final Report to Congress," (Vol. 1 1998), available at https://www3.epa.gov/ttn/utox/eurtc1.pdf, at ES-27, 7-45.

firing.[26] Pulverized coal firing is performed by feeding small particle sized coal—around 50 micron mean diameter—to a combustion chamber or furnace for combustion of the pulverized coal.[27] Illustrated below is a typical pulverized coal-fired power plant, known since at least 1992, with a Carolina-type design boiler shaded in orange and labeled as the "steam generator" to show where the combustion chamber is situated with respect to the other major systems in use by electric utilities.[28]



95. Regardless of the configuration of the combustion chamber, the components within these systems generally included a number of burners that fired the pulverized coal as it was carried from the pulverizers by a stream of primary air supplied by a large forced draft fan. It was known that the combustion chamber may also include a supply of secondary air and over-fire air ports for the control of NOx

[26] *See* Ex. 1027 (B&W: Steam) at 13-1 (noting also use of cyclone, stoker, and fluidized bed firing methods).
[27] *See* Ex. 1027 (B&W: Steam) at 13-1.
[28] *See* Ex. 1027 (B&W: Steam) at Plate 8.

formation. At the base of the combustion chamber would typically be a bottom ash handling system to collect and remove the portion of ash that was discharged from the furnace and settled at the bottom of the combustion chamber.

96. Although the term "boiler" was colloquially used to refer to an overall system, technically the boiler of an electric utility power plant referred principally to the tubes of the steam-water circulation system that were in contact with the hot gases from the combustion of the pulverized coal.[29] These tubes carried liquid water through them which, when in contact with the hot gases of the furnace, boiled the water (hence the term "boiler") to generate the steam necessary to drive the turbines and produce electricity. The boiler tubes were generally grouped in banks of steam and water tubes hung on stringers that were located in the top regions of the furnace and within the backpass of the furnace before the air preheater. The various stages of the steam tube banks were generally referred to as superheaters—these may be primary superheaters, secondary superheaters, and reheat superheaters.[30] The steam from the various boiler banks typically would be directed to different pressure stages of the turbine and then returned to another bank of water tubes before making a complete loop. Beyond the superheater banks of the boiler ordinarily would be a bank of water tubes called an "economizer," for the purpose of recovering extra

[29] *See* Ex. 1027 (B&W: Steam) at 18-1.
[30] *See* Ex. 1027 (B&W: Steam) at 18-2, 3.

thermal energy from the flue gases to be provided to the boiler feedwater before it entered superheater banks.[31] It was known that the point within the furnace after the last bank of the superheater section, and before the entrance to the economizer, was commonly referred to as the "furnace exit" and was understood as the transition point after which the combustion gases were referred to as flue gases from there forward.

97. It was known that after passing through the boiler section of the furnace, the flue gases pass through the economizer and another heat exchanger called an "air heater" or an "air preheater." The function of this air preheater was to reclaim some of the thermal energy from the combustion gases, by transferring this waste heat to the primary and secondary air before it enters the combustion chamber, thus enhancing the combustion of the pulverized coal.[32] After exiting the economizer, the cooler flue gases enter the flue-gas cleaning system responsible for pollution controls, prior to exhausting these gases to the environment.

3. Components Typically Upstream of the Combustion Chamber and Boiler

98. It was known in the art that upstream of the combustion chamber and boiler system was the air supply for the primary air and secondary air, as well as the coal handling systems.[33] Coal handling systems transport coal from the coal storage

[31] *See* Ex. 1027 (B&W: Steam) at 19-1.
[32] *See* Ex. 1027 (B&W: Steam) at 19-6.
[33] Ex. 1027 (B&W: Steam) at 13-3.

pile, typically on a conveyor system, to a coal bunker for temporary storage ahead of the pulverizers.'[34] These coal bunkers were typically situated vertically above the number of pulverizers so that the coal can be gravity fed to the feeder below.[35] These feeders meter the rate of coal provided to the pulverizers which, as the name implies, were responsible for crushing the coal with a series of rollers that grind the coal into a powder, typically under 74 microns in diameter.[36] It was known that a stream of primary air from the air preheater serves a dual purpose of drying out the coal and transporting the pulverized coal to the burners in the furnace.[37]

4. Flue Gas Constituents

99. In 1972, the EPA first published AP-42, *Compilation of Air Pollutant Emissions Factors.*[38] The Fifth Edition of AP-42 was published in January 1995 with various supplements and updates periodically provided.[39] Chapter 1 of the AP-42 is titled "External Combustion Sources." Chapter 1 of the AP-42 has a first section titled "Bituminous and Subbituminous Coal Combustion[40]."'The Bituminous and Subbituminous Coal Combustion section was last supplemented in September

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[34] See Ex. 1027 (B&W: Steam) at 11-13.
[35] See Ex. 1027 (B&W: Steam) at 11-13.
[36] See Ex. 1027 (B&W: Steam) at 12-8.
[37] See Ex. 1027 (B&W: Steam) at 12-2.
[38] See U.S. EPA, AP-42: Compilation of Air Emissions Factors, EPA (2019), available at https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors (last visited Apr 10, 2020).
[39] See U.S. EPA, AP-42: Compilation of Air Emissions Factors, EPA (2019), available at https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors (last visited Apr 10, 2020).
[40] See U.S. EPA, AP-42: External Combustion Sources, Chapter 1: Fifth Edition, Volume I, available at https://www3.epa.gov/ttn/chief/ap42/ch01/index.html (last visited Apr 10, 2020).

1998.[41].Thus , in 2003, the AP-42 demonstrated that much was already known in the art about flue gas constituents.

100. The AP-42 explained that "[e]missions from coal combustion depend on the rank and composition of the fuel, the proportions of fuel and air, the type and size of the boiler, firing conditions, load, type of control technologies, and the level of equipment maintenance."[42] It was known that potential emissions included particulate matter, sulfur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), organic compounds, trace metals, acid gases, and greenhouse gases.[43]

101. Particulate matter emitted from coal combustion processes "include[d] the ash from combustion of the fuel as well as unburned carbon resulting from incomplete combustion."[44] It was also known that in typical pulverized coal operations, complete combustion resulted in particulate matter that "is primarily composed of inorganic ash residues."[45] In particular, the ash that is entrained in the flue gas was commonly referred to as "fly ash."[46] Unburned carbon in fly ash was estimated as the loss-on-ignition (LOI), which is the mass fraction of combustibles lost during incineration of a fly ash sample in air. In general, LOI is greater when

[41] U.S. EPA, AP-42: External Combustion Sources, Chapter 1: Fifth Edition, Volume I, available at https://www3.epa.gov/ttn/chief/ap42/ch01/index.html (last visited Apr 10, 2020).
[42] Ex. 1053 (Chapter 1 of AP-42) at 1.1-3.
[43] Ex. 1053 (Chapter 1 of AP-42) at 1.1-3 to 1.1-6.
[44] Ex. 1053 (Chapter 1 of AP-42) at 1.1-3.
[45] Ex. 1053 (Chapter 1 of AP-42) at 1.1-3.
[46] Ex. 1053 (Chapter 1 of AP-42) at 1.1-3.

in-furnace technologies are implemented to reduce NOx emissions. LOI is also greater with coals of progressively higher rank.

102. It was known that sulfur oxides ("SO_x") that were emitted from coal combustion "form[ed] as the organic and pyritic sulfur in the coal [were] oxidized during the combustion process."[47] In fact, it was well known that "about 95 percent of the sulfur present in bituminous coal [was] emitted as gaseous SO_x, whereas somewhat less [was] emitted when subbituminous coal is fired."'[48] The SO_x emissions were known to be "primarily sulfur dioxide (SO_2), with a much lower quantity of sulfur trioxide (SO_3) and gaseous sulfates."[49]

103. It was known that nitrogen oxide ("NO_x") emissions "result[ed] from thermal fixation of atmospheric nitrogen in the combustion flame and from oxidation of nitrogen bound in the coal"[50]. NO_x emissions were known to be "primarily nitric oxide (NO)" with trace amounts of nitrogen dioxide (NO_2) and nitrous oxide (N_2O).[51]

104. It was known that organic compound emissions from coal combustion "include volatile, semivolatile, and condensable organic compounds either present

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47 Ex. 1053 (Chapter 1 of AP-42) at 1.1-3.
48 Ex. 1053 (Chapter 1 of AP-42) at 1.1-3.
49 Ex. 1053 (Chapter 1 of AP-42) at 1.1-3; see also U.S. DOE, How NOx is Formed, DOE NETL, available at
50 Ex. 1053 (Chapter 1 of AP-42) at 1.1-3 see also U.S. DOE, How NOx is Formed, DOE NETL, available at https://web.archive.org/web/20030426074529fw_/http://www.netl.doe.gov/coalpower/environment/nox/howN0x.html.
51 50 Ex. 1053 (Chapter 1 of AP-42) at 1.1-3.https://web.archive.org/web/20030426074529fw_/http://www.netl.doe.gov/coalpower/environment/nox/howN0x.html.

in the coal or formed as a product of incomplete combustion" such as "alkanes, alkenes, aldehydes, alcohols, and substituted benzenes (e.g., benzene, toluene, xylene, and ethyl benzene)."[52] It was also known that the rate at which these emissions are generated also "depends on the combustion efficiency of the boiler."[53] It was also known that similar to CO emissions, "combustion modifications that change combustion residence time, temperature, or turbulence may increase or decrease concentrations of organic compounds in the flue gas."[54]

105. It was known that the amount of trace metals (including mercury) emitted during coal combustion generally depends on "the physical and chemical properties of the metal itself; the concentration of the metal in the coal; the combustion conditions; and the types of particulate control devices used, and their collection efficiencies as a function of particle size."[55] In 2003, the types of trace metals were generally categorized into three classes:[56]

> Class 1: Elements that are approximately equally concentrated in the fly ash and bottom ash, or show little or no small particle enrichment. Examples include manganese, beryllium, cobalt, and chromium.

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52 Ex. 1053 (Chapter 1 of AP-42) at 1.1-4.
53 Ex. 1053 (Chapter 1 of AP-42) at 1.1-4.
54 Ex. 1053 (Chapter 1 of AP-42) at 1.1-4.
55 Ex. 1053 (Chapter 1 of AP-42) at 1.1-4 — 1.1-5.
56 Ex. 1053 (Chapter 1 of AP-42) at 1.1-5.

Class 2: Elements that are enriched in fly ash relative to bottom ash, or show increasing enrichment with decreasing particle size. Examples include arsenic, cadmium, lead, and antimony.

Class 3: Elements which are emitted in the gas phase (primarily mercury and, in some cases, selenium).

Class 1 emissions were known to be "directly related to control of total particulate matter emissions."[57] Class 2 emissions were known to "depend[] on collection of fine particulate."[58] However, it was known that "[b]ecause of the volatility of Class 3 metals, particulate controls have only a limited impact on emissions of these metals."[59]

106. It was known that coal combustion "also results in emissions of chlorine and fluorine."[60] The chlorine and fluorine were known to be "primarily in the form of hydrogen chloride (HCl) and hydrogen fluoride (HF)" but may also be found in lesser quantities as chlorine gas and fluorine gas.[61]

5. Components Downstream of the Combustion Chamber and Boiler

[57] Ex. 1053 (Chapter 1 of AP-42) at 1.1-5.
[58] Ex. 1053 (Chapter 1 of AP-42) at 1.1-5.
[59] Ex. 1053 (Chapter 1 of AP-42) at 1.1-5.
[60] Ex. 1053 (Chapter 1 of AP-42) at 1.1-5.
[61] Ex. 1053 (Chapter 1 of AP-42) at 1.1-5.

107. The EPA's AP-42 report also provided a brief summary of the various downstream components that were known to be used to control certain undesirable flue gas constituents.[62]

a. Particulate Matter Emissions Controls

108. Known particulate matter controls included "combustion modifications (applicable to small stoker-fired boilers) and post-combustion methods (applicable to most boiler types and sizes)."[63] Methods to control particulate matter emissions from small stoker-fired and hand-feed combustion sources included "employing good combustion practices such as operating within the recommended load ranges, controlling the rate of load changes, and ensuring steady, uniform fuel feed," as well as using "[p]roper design and operation of the combustion air delivery systems"[64]. It was also known that post-combustion control of particulate matter could be accomplished using one or more of the following: an electrostatic precipitator ("ESP"), a fabric filter (or baghouse), a wet scrubber, a cyclone or multiclone collector, or a side stream separator.[65]' It was known that electrostatic precipitators could be placed ahead of an air preheater, such as in the hot-side (HESP) configuration.

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62 See Ex. 1053 (Chapter 1 of AP-42) at 1.1-6 — 1.1-9.
63 Ex. 1053 (Chapter 1 of AP-42) at 1.1-6.
64 Ex. 1053 (Chapter 1 of AP-42) at 1.1-6.
65 Ex. 1053 (Chapter 1 of AP-42) at 1.1-6 to 1.1-7.

109. It was known that fabric filters contain multiple compartments that contain "several thousand long, vertically supported, small diameter fabric bags."[66] It was known that when mercury-containing flue gas with flyash pass through the bags, they deposit flyash and unburned carbon onto thin dust cakes on their outer surfaces. The cleaned flue gas then moves into an outlet plenum that recombines the effluents from all bags to proceed further downstream. It was known that as the dust cake accumulates, the increasing pressure drop across the filter is managed by pulsing air jets to dislodge the dust cake into collection hoppers.

b. SO_x Emissions Controls

110. Multiple techniques were known for controlling SO_x emissions. For example, it was known that "[p]ost combustion flue gas desulfurization (FGD) techniques can remove SO_2 formed during combustion by using an alkaline reagent to absorb SO_2 in the flue gas."[67] These FGD systems would treat coal flue gas "using wet, dry, or semi-dry desulfurization processes of either the throwaway type (in which all waste streams are discarded) or the recovery/regenerable type (in which the SO_2 absorbent is regenerated and reused)."[68] The most common type of FGD systems were wet FGDs that "generally use alkali slurries as the SO_2 absorbent medium and can be designed to remove greater than 90 percent of the incoming

66 Ex. 1027 (B&W: Steam) at 33-7
67 Ex. 1053 (Chapter 1 of AP-42) at 1.1-7.
68 Ex. 1053 (Chapter 1 of AP-42) at 1.1-7.

SO_2."[69] It was known that commercially viable and accepted wet FGDs include lime/limestone scrubbers, sodium scrubbers, and dual alkali scrubbers.[70]

c. NO_x Emissions Controls

111. It was known that NO_x emissions could be controlled using combustion control techniques and post-combustion control.[71] Known post-combustion control techniques included "selective noncatalytic reduction (SNCR) and selective catalytic reduction (SCR)" systems.[72]

112. SNCR systems were known to "involve[] injecting ammonia (NH_3) or urea into specific temperature zones in the upper furnace or convective pass."[73] The SNCR system was known to remove NO_x by reacting the ammonia or urea with NO_x in the flue gas to produce nitrogen and water.[74] Specifically, it was known that "[a] nitrogen based reducing agent (reagent), such as ammonia or urea, is injected into the post combustion flue gas."[75] Although it was known that the nitrogen-based reducing agent would react with numerous components in the flue gas stream, "the NO_x reduction reaction is favored over other chemical reaction processes for a

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69 Ex. 1053 (Chapter 1 of AP-42) at 1.1-7.
70 Ex. 1053 (Chapter 1 of AP-42) at 1.1-7.
71 Ex. 1053 (Chapter 1 of AP-42) at 1.1-7 to 1.1-8.
72 Ex. 1053 (Chapter 1 of AP-42) at 1.1-8.
73 Ex. 1053 (Chapter 1 of AP-42) at 1.1-9.
74 Ex. 1053 (Chapter 1 of AP-42) at 1.1-9.
75 U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 1 Selective Noncatalytic Reduction (October 2000), available at https ://www3.epa.gov/ttn/ecas/docs/cs4-2chl.pdf, at 1-4

specific temperature range and in the presence of oxygen."[76] Typical SNCR units in the early 2000's provided "30% to 50% NO_x reduction" with known potential "NO_x reduction efficiencies of up to 75 percent."[77].

113. Known SCR systems operated in a similar way that "involves injecting NH_3 into the flue gas in the presence of a catalyst to reduce NO_x to nitrogen and then water." Similar to SNCR systems, it was known that "the SCR process is based on the chemical reduction of the NO molecule."[78] The known SCR systems differed from known SNCR systems because they "employ[] a metal-based catalyst with activated sites to increase the rate of the reduction reaction.:[79] Similar to known SNCR systems, "[a] nitrogen based reducing agent (reagent), such as ammonia or urea, is injected into the post combustion flue gas"[80]. The SCR reactor was known to be flexible and could "be located at various positions in the process including before an air heater and particulate control device, or downstream of the air heater,

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[76] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 1 Selective Noncatalytic Reduction (October 2000), available at https ://www3.epa.gov/ttn/ecas/docs/cs4-2chl.pdf, at 1-4.

[77] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 1 Selective Noncatalytic Reduction (October 2000), available at https ://www3.epa.gov/ttn/ecas/docs/cs4-2chl.pdf, at 1-3.

[78] 77 U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-4

[79] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-4.

[80] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-4.

particulate control device, and flue gas desulfurization systems."[81] It was known that SCR systems were "often designed to meet control targets of over 90%" but typically "operate at efficiencies in the range of 70% to 90%" NO_x reduction.[82]

114. By January 2004, it was also known that adding a halogen "also reduces NO_x emissions in a selective catalytic reduction (SCR) and/or (SNCR) process, especially if the additive is injected with a nitrogen agent (N-agent) into NO_x and O_2 containing flue gas at flue gas temperatures in a range of 1600° F. (Fahrenheit) to 2300° F."[83] Specifically, it was known that "[t]he halogen additive can also be added with ammonia, urea or other N-agent solution ... to increase efficiency of NO_x reduction."[84]

115. By 2002, it was known that the catalysts in SCR units could also oxidize elemental mercury (Hg^0) while they eliminated NOx from the flue gas. Field tests across several SCRs at commercial power plants indicated that SCR systems "may also promote Hg^0 oxidation to Hg^{2+}, and this effect appeared to be coal-specific and possibly catalyst-specific."[85] The coal-specific aspect was attributed to a coal's native chlorine content, as researchers interpreting the full-scale SCR field test data

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81 Ex. 1053 (Chapter 1 of AP-42) at 1.1-9.

82 U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6' Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-3.

83 Ex. 1036 (Lissianski) at 3:51-55.

84 Ex. 1036 (Lissianski) at 4:40-42.

85 Ex. 1037 (Power Plant Evaluation).

noted that significant increases in mercury oxidation (to Hg^{2+}) across the SCR that "correlate[s] with the amount of chloride in the coal."[86]

116. Thus, a POSITA would have readily realized that adding chlorine compounds to the coal or furnace to produce HCl in flue gas would promote oxidation of elemental mercury across an SCR. It would have been a very simple extension to recognize that other halogens, particularly Br, would promote mercury oxidation on SCR catalysts as well as, or better than, chlorine.

d. Mercury Emissions Controls

117. By February 2003, numerous projects had been completed that demonstrated components for effective mercury control from coal-fired power plants.[87] For example, in Colorado "the DOE/FETC Mega PRDA program, DOE, Public Service Company of Colorado (PSCo), and EPRI" funded an evaluation of "carbon injection as a mercury control technology. ADA Technologies performs the fabrication, pilot operation, and reporting."[88] Further research in Colorado sponsored by TDA evaluated "a low cost route to a carbon-based, sulfur containing sorbent that should have a high capacity for mercury and also for other air toxins including

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[86] Ex. 1045 (Laudal).

[87] U.S. DOE, Completed Mercury Projects, February, 2003, available at https://web.archive.org/web/20030227051517fw_/http:/www.netl.doe.gov/coalpower/environment/mercury/index.html.

[88] 87 U.S. DOE, Completed Mercury Projects, February, 2003, available at https ://web. archive. org/web/20030227051517fwjhttp :/www.netl. doe .gov/coalpower/environment/mercury/index.html.

chlorine and hydrogen chloride."[89] Similarly, testing in Pennsylvania evaluated "the use of a granular activated carbon (GAC) fixed bed adsorption system for mercury adsorption from flue gas."[90]

118. By March 2003, Apogee completed its proposal to the DOE "to test novel and less mature technologies."[91] At that time, the DOE explained that "[u]nder the laboratory sorbent development program supported by EPRI, over 1000 potential sorbents have been evaluated and many promising low cost mercury sorbents and processes have been identified."[92] Thus, "a portable pilot system fabricated by Apogee for EPRI" was designed to provide fixed bed testing of 6 to 12 of these novel sorbents.[93] Also by March 2003, Babcock and Wilcox completed testing to "demonstrate their wet scrubbing mercury removal technology (which uses very small amounts of a liquid reagent to achieve increased mercury removal)."[94]

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[89] U.S. DOE, Completed Mercury Projects, February, 2003, available at https ://web . archive. org/web/20030227051517fw_/http :/www.netl. doe .gov/coalpow er/environment/mercury/index.html.

[90] U.S. DOE, Completed Mercury Projects, February, 2003, available at https://web.archive.org/web/20030227051517fw_/http:/www.netl.doe.gov/coalpower/environment/mercury/index.html.

[91] U.S. DOE, Control Technology Assessment Of Low Cost Novel Mercury Sorbents, March, 2003, available at https ://web. archive. org/web/20030315093024fwjhttp :/www.netl. doe. gov/coalpow er/environment/mercury/control-tech/hg-sorbents.html.

[92] U.S. DOE, Control Technology Assessment Of Low Cost Novel Mercury Sorbents, March, 2003, available at https ://web . archive. org/web/20030315093024 fw_/http :/www.netl. doe. gov/coalpow er/environment/mercury/control-tech/hg-sorbents.html.

[93] U.S. DOE, Control Technology Assessment Of Low Cost Novel Mercury Sorbents, March, 2003, available at https ://web . archive. org/web/20030315093024 fw_/http :/www.netl. doe. gov/coalpow er/environment/mercury/control-tech/hg-sorbents.html.

[94] U.S. DOE, Control Technology Full-Scale Testing of Enhanced Mercury Control in Wet FGD, March, 2003, available at https ://web. archive. org/web/20030315095234 fw_/http :/www.netl. doe. gov/coalpow er/environment/mercury/control-tech/test-wet-fgd.html.

C. SORBENTS / ACTIVATED CARBON

1. Sorbent Overview

119. In the late 1990's and early 2000's, sorbent technology was already used to remove mercury, and researchers were investigating methods to reduce costs and improve the effectiveness of sorbents. In particular, research by the EPA in the mid-1990s suggested that "activated carbon has been shown to be a promising technology."[95] Activated carbon's general use as a sorbent dates back as far as 1500 B.C. where the ancient Egyptians used carbonized wood "as an adsorbent for medicinal purposes and also as a purifying agent."[96] Industrial production of activated carbon "was established in 1900-1901 in order to replace bone char in the sugar refining process."[97] It was known in the 1980s that activated carbons "are excellent adsorbents and thus are used to purify, decolorize, deodorize, dechlorinate, detoxicate, filter, or remove or modify the salts, separate, and concentrate in order to permit recovery."[98] It was known that "adsorption" refers to a process by which an adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent.

120. By the 1930's, it was known that activated carbon could be used for mercury capture in gas streams.[99] U.S. Patent No. 1,984,164 to Stock, issued in

[95] Ex. 1060 (EPA 1997 Mercury Study Report Vol. VIII) at 2-54.
[96] Ex. 1070 (Bansal) at vii.
[97] Ex. 1070 (Bansal) at vii.
[98] Ex. 1070 (Bansal) at viii.
[99] Ex. 1029 (Stock).

1934, explained that "[i]t has already been suggested to employ active carbon as a means of protection against the effects of mercury vapors."[100] By 1998, "[a]ctivated carbons ha[d] been the most thoroughly studied sorbent for the capture of mercury."[101] Additionally, many research programs completed by 2003 had shown that activated carbon injection ("ACI") in coal-fired power plants had "the most promise as a near-term mercury control technology."[102]

121. By 1998, it was known that sorbents may capture mercury from coal flue gas by "chemical adsorption, or by chemical reaction.[103] Chemisorption was known to refer to "a surface reaction, limited to a monolayer."[104] Chemisorption and chemical reaction processes both were known to "occur over a wide range of temperatures" and "typically have higher activation energies and heats of reaction than does physisorption."[105]

122. By January 2004, the EPA had already proposed rules relating to mercury emissions, and had identified "types of sorbent that may be viable for use in sorbent injection [that] include two basic types of activated carbon (AC; regular and impregnated)."[106] Of these two types of promising sorbents—regular activated carbon and chemically-impregnated activated carbons—the EPA identified

[100] Ex. 1029 (Stock) at 1:27-30.
[101] Ex. 1038 (Granite) at 22.
[102] Ex. 1039 (Feeley) at 10.
[103] Ex. 1038 (Granite) at 4.
[104] Ex. 1038 (Granite) at 5.
[105] Ex. 1038 (Granite) at 5.
[106] Ex. (EPA-Proposal) at 4676.

SorbalitTM and Darco FGD as brand-name activated-carbon sorbents of interest and indicated that chemically-impregnated activated carbons being studied included those using halogens and sulfur "bound to the [activated carbon] to enhance mercury removal.[107]

2. Well-Known Structure of Activated Carbon

123. By 1988, it was well known that activated carbon would adsorb oxidized mercury ions (Hg2+ or Hg(II)).[108] The surface structure of activated carbon (also referred to as "active carbon"), and the interaction with mercury and halogens, was discussed in a textbook authored in 1988 by Roop Chand Bansal and others, entitled "Active Carbon." Sections of this book have been included as Exhibit 1070 to my declaration, and I refer to it as "Bansal."[109] Bansal describes "the basic steps involved in the manufacture of activated carbons, the selectivity and suitability of different raw materials, and the probable mechanism of the physical and chemical activation processes."[110]

124. Bansal explains that "[a]ctivated carbons are unique and versatile adsorbents because of their extended surface area, microporous structure, universal adsorption effect, high adsorption capacity, and high degree of surface reactivity."[111]

[107] Ex. (EPA-Proposal) at 4676.
[108] Ex. 1070 (Bansal) at 391.
[109] Ex. 1070 (Bansal).
[110] Ex. 1070 (Bansal) at iv.
[111] Ex. 1070 (Bansal) at iii.

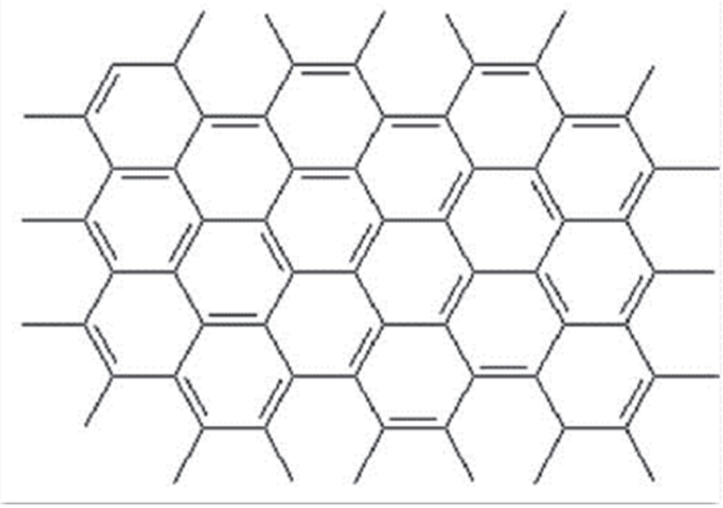
Specifically, Bansal teaches that activated carbons "are extensively used to purify, decolorize, deodorize, dechlorinate, and detoxicate potable waters; for solvent recovery and air purification in inhabited spaces such as restaurants, food processing, and chemical industries; in the purification of many chemical and foodstuff products; and in a variety of gas phase applications."[112]

125. Bansal explains in 1988 that the adsorbent properties of activated carbon were known to be "attributed to their large surface area, a high degree of surface reactivity, universal adsorption effect, and favorable pore size, which makes the internal surface accessible, enhances the adsorption rate, and enhances mechanical strength."[113] By the 1980s, it was known that "commercial active carbons have a specific surface area of the order of 800-1500 m2/ g."[114] It was known that the surface area of activated carbon may be "contained predominantly within micropores, which have effective diameters smaller than 2 nm."[115] A typical activated carbon particle was known to be "made up of a complex network of pores which have been classified into micropores (diameters < 2 nm), mesopores (diameter between 2 and 50 nm), and macropores (diameters > 50 nm)."[116] Although the "macropores do not contribute much toward surface area," it was known that they

[112] Ex. 1070 (Bansal) at iii.
[113] Ex. 1070 (Bansal) at viii.
[114] Ex. 1070 (Bansal) at viii.
[115] Ex. 1070 (Bansal) at viii.
[116] Ex. 1070 (Bansal) at viii.

"act as conduits for the passage of the adsorbate into the interior mesopore and the micropore surface where most of the adsorption takes place."[117]

126. It was known that an activated-carbon sorbent generally is formed from graphene sheets (or layers). The Bansal reference in 1988 described activated carbon as having "a st[r]ucture consisting of sheets of aromatic condensed ring systems stacked in nonpolar layers."[118] This can be pictured as a stack of sheets of the following structure:



Each vertex in the above structure represents a carbon atom, and each hexagon in the above figure represents an aromatic ring.

127. Each such graphene sheet was known to have "limited dimensions and therefore present edges."[119] Further, it was known that "these sheets are associated

[117] Ex. 1070 (Bansal) at viii.
[118] Ex. 1070 (Bansal) at 238.
[119] Ex. 1070 (Bansal) at 238.

with defects, dislocations, and discontinuities."[120] In particular, the location and number of these defects, dislocations, and discontinuities could depend, among other things, on the particular relationship between the graphene sheets. It was known that once a carbon atom is partially exposed from a sheet at a discontinuity, a pair of its valence electrons are no longer able to be delocalized into (shared by) the surrounding carbon atoms. This pair of electrons becomes localized to its parent carbon atom, instead of interacting with its neighbors. Such carbons were known to "have unpaired electrons and residual valences and are richer in potential energy."[121] Thus, research showed that "these carbon atoms are highly reactive and constitute active sites or active centers."[122] Bansal emphasized "[t]he importance of active sites and their characterization and of active surface area and its measurement in determining the reactivity of carbons."[123]

3. Reaction Between Activated Carbon and Halogens

128. It was known that activated carbon "can also fix nitrogen on treatment with ammonia; sulfur on treatment with hydrogen sulfide, carbon disulfide, or sulfur; chlorine on treatment with the gas; and bromine on treatment in the gaseous or solution phase" that "give rise to stable carbon-nitrogen, carbon-sulfur, carbon-chlorine, or carbon-bromine surface structures (surface compounds)

[120] Ex. 1070 (Bansal) at 238.
[121] Ex. 1070 (Bansal) at 238.
[122] Ex. 1070 (Bansal) at 238.
[123] Ex. 1070 (Bansal) at iv.

respectively."[124] Additionally, "[x]-ray diffraction studies have shown that these heteroatoms or molecular species are bonded or retained at the edges and corners of the aromatic sheets or to carbon atoms in defect positions of the aromatic sheets, or they can be incorporated within the carbon layer, forming heterocyclic ring systems."[125] In other words, the Bansal reference explained in 1988, based on surface chemistry studies, that activated carbon has reactive carbenes (lone pairs of electrons) at the edge sites of graphene sheets, and that bromine bonds to these sites.

129. In 1970, it was documented that almost 100 years ago, researchers had reported that substantial loadings of both chlorine (Cl) and bromine (Br) can be bound onto carbon sorbents by simply heating them under gas mixtures containing the molecular (Cl2, Br2) or acid halide (HCl, HBr) forms of the halogens, among other methods.[126] For example, it was shown that a sugar charcoal bound 24 % Cl by weight and a coconut charcoal bound 40 wt. % Cl.[127] Similarly, it was shown that charcoal bound up to a saturation limit (adsorption equilibrium) of 38 wt. % Br, and carbon black bound up to a saturation limit (adsorption equilibrium) of around 31 wt. % Br.[128] A person of ordinary skill in the art would expect that in an actual industrial application, the amount of Br actually bound would be less than the

[124] Ex. 1070 (Bansal) at 259.
[125] Ex. 1070 (Bansal) at 259.
[126] Ex. 1042 (Puri) at 255-57.
[127] Ex. 1042 (Puri) at 256-57.
[128] Ex. 1042 (Puri) at 260.

saturation limit. Halogens onto activated carbon would have been bound to similar amounts as with carbon black. Binding refers to the element to element chemical bonding of Cl or Br with activated carbon, whereas loading refers to a weight ratio. It was known that the loading of Br is greater than that for Cl at the same conditions, because Br has a greater molecular weight than Cl (79.9 vs. 35.5 g/mol).[129] It was known that both halogens are bound in rough proportion to the hydrogen content of the carbon sorbent.[130] Thus, it was known that even in situations where Br was bound on a lower mole-to-mole basis than Cl under the same thermal conditions, its overall loading is greater due to the disparity in molecular weights.[131] Additionally, for mercury removal at electric utility boilers, research by the EPA in the mid-1990s suggested that "even greater mercury removal may be possible with impregnated activated carbons" above what was already well understood for untreated sorbent injection.[132]

4. Reaction Between Activated Carbon and Mercury

130. It was widely understood in the late 1990's that only sorbents that bound both elemental and oxidized mercury by chemical adsorption (a.k.a. chemisorption) and chemical reaction were suitable, because this form would not be leached into the groundwater from flyash holding ponds or otherwise released during

[129] Ex. 1042 (Puri) at 260.
[130] Ex. 1042 (Puri) at 257 (chlorine) and 260 (bromine).
[131] Ex. 1042 (Puri) at 261.
[132] Ex. 1060 (EPA 1997 Mercury Study Report Vol. VIII) at 2-54.

flyash disposal.[133] In 1999, researchers demonstrated that mercury formed chemical bonds with the species on activated carbons exposed to simulated coal-derived flue gas.[134] Researchers found that with carbon sorbents promoted by iodine and sulfur, "the XAFS data confirm that it is the activating element (I or S) that forms a sorption complex with mercury."[135] Researchers also found that with unpromoted activated carbon exposed to flue gas that contained HCl and SO2, the XAFS spectra showed that, first, HCl was bound to the carbon and then, elemental and oxidized Hg were bound to the chlorinated surface sites on the carbon.[136] The XAFS spectra "indicate that the LAC carbon readily sorbs a form of chlorine present in the synthetic flue gas", and that the chlorinated surface bonds to mercury "with Hg2+-Cl, as in HgCl2, and/or Hg2+-S, as in HgS (cinnabar)."[137]

131. By 2004, these findings had been generalized to interpret both oxidation and capture of elemental and oxidized mercury on both inherent unburned carbon and injected activated-carbon sorbents.[138] As my team and I explained in a paper from 2004:

> Mercury transformations occur while flue gases are cooled along an exhaust system. At the superheater section, only Hg0 is present and the carbon is oxidized but otherwise clean. The process begins when temperatures are cooled into the range where HCl chlorinates some of

[133] Ex. 1038 (Granite) at 40.
[134] Ex. 1043 (XAFS) at 119.
[135] Ex. 1043 (XAFS) at 114.
[136] Ex. 1043 (XAFS) at 117, 119.
[137] Ex. 1043 (XAFS) at 117, 119.
[138] Ex. 1044 (Hg Speciation)

> the carbon sites in a reversible reaction. With further cooling, Hg0 adsorbs at appreciable rates onto the chlorinated sites. Since desorption remains relatively fast, the HgCl rapidly desorbs into the gas phase, where it oxidizes into HgCl2. In this temperature range, there is little sorption but extensive oxidation. As the particles are cooled further, the desorption rate becomes controlling, which implies that surface coverage increases, ultimately, to the equilibrium sorption capacity . . . . And HgCl on the carbon surface constitutes sorbed or "particulate" Hg.[139]

132. By 2004, a POSITA would have known that chlorine in coal would be released into flue gas as HCl, which is spontaneously bound to inherent unburned carbon and injected carbon sorbents.[140] The POSITA would also know that the chlorinated sites on the carbon would oxidize elemental Hg at economizer temperatures, and irreversibly capture the elemental and oxidized Hg on the carbon at air preheater temperatures and cooler.[141]

5. Sorbent Injection Rate Affects Mercury Removal

133. It was widely understood to a person of ordinary skill in the art in the early 2000s that by adjusting the sorbent injection rate, one could control mercury emissions. In 2002, ADA-ES, a prominent company providing mercury mitigation, recognized that the "amount of carbon [sorbent] injected" was one of a number of "factors [that] may influence the mercury removal obtained with sorbent injection upstream" of a particulate collector—other generalized factors include the type of

[139] Ex. 1044 (Hg Speciation) at 4-5.
[140] Ex. 1044 (Hg Speciation) at 5.
[141] Ex. 1044 (Hg Speciation) at 5.

sorbent, the injection method, and flue gas conditions.[142] By December 2003, if not earlier, the EPA drafted proposed rules (discussed in more detail in the sections below) that when using sorbents such as activated carbon, the "extent of potential Hg removal is dependent on: (1) Efficient distribution of the sorbent (e.g., activated carbon) in the flue gas; (2) the amount of sorbent needed to achieve a specific level of Hg removal which will vary depending on the fuel being burned."[143]

134. Injection rates are commonly represented as "injection concentration in lb/MMacf,"[144] which stands for pounds of activated carbon per 1 million actual cubic feet of flue gas. To account for variabilities in coal, it was known to use injection rates between 0 and 30 lb/MMacf, as represented by Figures 1-6 of the 2002 ADA-ES article.[145] However, by 2002, engineers had determined to generally use approximately 10 lb/MMacf activated carbon to remove mercury, finding that the "maximum removal [is] achievable at injection concentrations between 5 and 10 lb/MMacf" with "little improvement . . . above 10 lb/MMacf."[146] Ultimately, it was known that the selected injection rate of the sorbent material comes down to routine design tradeoffs between the "effectiveness and costs associated"[147] with increased rates of the injected sorbent among other routine design parameters.[148]

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[142] Ex. 1059 (Field Studies of Mercury Control) at p. 2.
[143] Ex. 1009 (EPA-Proposal) at 4676 (emphasis added).
[144] Ex. 1059 (Field Studies of Mercury Control) at 5.
[145] Ex. 1059 (Field Studies of Mercury Control) at Figures 1-6.
[146] Ex. 1059 (Field Studies of Mercury Control) at 13.
[147] Ex. 1059 (Field Studies of Mercury Control) at 2.
[148] Ex. 1059 (Field Studies of Mercury Control) at 4-5.

D. MARKET DEMAND AND INDUSTRY TRENDS

135. As a direct result of the regulatory actions and intentions promulgated by the EPA, and funding provided by the DOE NETL, the American electric power utility industry mobilized a massive response to develop and evaluate technologies for mercury-emissions control as soon as the ICR database was assimilated at EPA in 2000.[149] Immediately afterward, findings of the industry's R&D programs were fast-tracked and widely disseminated to industry leaders at technical conferences, primarily at the MEGA, AWMA, and EUEC conferences from 1998 and 1999 onward, and at Air Quality from 2002 onward.

136. By the early 2000s, the DOE and NETL had funded projects, and been provided with successful large-scale demonstrations, of mercury capture from coal-fired power plants.[150] As Thomas Feeley of the NETL stated in 2003 in summarizing the history of mercury removal, the early goal of the DOE was to "develop mercury control technologies that can achieve 50 to 70% mercury capture at three-quarters or less than current estimated costs for powdered activated carbon injection."[151] The longer-term goals were "to develop advanced mercury control technologies to achieve 90% or greater capture at one-half to three-quarters the cost of existing

[149] Ex. 1039 (Feeley).
[150] Ex. 1039 (Feeley) at 11.
[151] Ex. 1039 (Feeley) at 11.

technology and that would be available for commercial demonstration by 2010."[152]

137. To meet these goals, the DOE and various industry partners co-sponsored numerous mercury removal testing projects. For example, the DOE co-sponsored projects with industry partners including, but not limited to, UND EERC, ADA-ES Inc., Babcock & Wilcox, Mobotec USA, Southern Company, URS, Sorbent Technologies Corporation, SaskPower, ALSTOM Power, Inc., GE EER, and Amended Silicates, LLC.[153] The testing with these industry partners was focused on meeting or exceeding the DOE's targets.

138. As discussed above, the NETL launched a three-phase plan for mercury-control research.[154] The first phase of testing was for so-called inherent mercury controls that relied on existing air pollution control devices (APCDs), including ESPs, fabric filters (FF), SCRs, and FGDs.[155] The second phase of testing characterized activated carbon injection (ACI) installations, and a third phase covered halogenated sorbents, SDAs, and halogen/lime injections.[156] Before 2004, almost all these phases of testing had been run mostly at about 20 plants operated by regional utility companies and cooperatives.

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[152] Ex. 1039 (Feeley) at 11.
[153] *See* U.S. DOE, Mercury Information Clearinghouse Final Report (Apr. 2006), available at https://www.osti.gov/servlets/pur1/907884, at 14-16.
[154] Ex. 1039 (Feeley) at 2.
[155] Ex. 1039 (Feeley) at 2.
[156] Ex. 1039 (Feeley) at 2.

E. EPA REGULATIONS TO REDUCE MERCURY EMISSIONS

139. By the 1990's, it was known that excess mercury in the environment can pose a significant threat to the health and safety of plants, birds, and mammals.[157] In particular, it was known that mercury may cause death, reduced reproductive success, impaired growth, and developmental/behavioral abnormalities.[158] The 1990 Clean Air Act Amendments ("CAAA") - specifically, Section 112(b) - listed various hazardous air pollutants ("HAPs") and details the relevant regulatory foundation for Hg (and other) emissions that were to be regulated by establishing national emissions standards.[159] For control of HAPs, the CAAA required the maximum degree of reduction in emissions of the regulated pollutant.[160] Specifically, the EPA issued maximum available control technology ("MACT") standards that were based on the average emission level achieved by controls on the best performing 12 percent of existing sources, by category of industrial and utility sources,[161]

140. The EPA conducted several field test programs to assess contributions from the electric power utility industry to the total emissions inventories for the

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[157] U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https: //www.epa.gov/sites/production/files/2015-09/documents/volumel.pdf, at 2-6.
[158] U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https: //www.epa.gov/sites/production/files/2015-09/documents/volumel.pdf, at 2-6.
[159] U.S. EPA, "Background Information on Mercury Sources and Regulations," available at https: //web.archive.org/web/20030419191659/http: /www.epa.gov/grtlakes/bnsdocs /mercsrce/mercreg.html.
[160] Ex. 1054 (Mercury Emissions Control).
[161] Ex. 1054 (Mercury Emissions Control).

regulated HAPs.[162] For the mercury-emissions inventory prepared by EPA from tests in 1994 —1995, coal-fired power plants accounted for one-third of the total mercury in the environment.[163]

141. During the next few years, the EPA surveyed the technical information needed to both refine the Hg emissions inventory and to contemplate Hg emissions control technologies, should federal regulations on Hg emissions be enacted.[164] This period laid the foundation for EPA's Information Collection Request ("ICR") to coal-fired utility operators, which began implementation in late 1998 and was carried out from 1999-2000.[165]

142. In the early 2000's, the EPA announced that regulations on mercury-emissions from coal-fired power plants were both appropriate and necessary.[166] The timetable for the national emissions standard for mercury was initially set for the EPA to propose the standard by December 2003 and to finalize a standard by December 2004.[167]

143. On March 15, 2005, the "EPA issued the first-ever federal rule to permanently cap and reduce mercury emissions from coal-fired power plants," titled the Clean Air Mercury Rule (CAMR), which builds on the "EPA's Clean Air

[162] Ex. 1039 (Feeley) at 4.
[163] Ex. 1039 (Feeley) at 3.
[164] Ex. 1039 (Feeley) at 4-7.
[165] Ex. 1039 (Feeley) at 4.
[166] Ex. 1039 (Feeley) at 7-8.
[167] Ex. 1039 (Feeley) at 8.

Interstate Rule (CAIR) to significantly reduce emissions from coal-fired power plants."[168] The EPA explained that "these rules will reduce utility emissions of mercury from 48 tons a year to 15 tons, a reduction of nearly 70 percent."[169] In a press release posted on March 15, 2005, the EPA announced the signing of the CAMR and emphasized the "70 percent" reduction in mercury emissions:

> (Washington, D.C. -- 03/15/05) Acting Administrator Steve Johnson will sign today the Clean Air Mercury Rule, a rule that will significantly reduce mercury emissions from coal-fired power plants across the country. Taken together, the recently issued Clean Air Interstate Rule and the new Clean Air Mercury Rule will reduce electric utility mercury emissions by nearly 70 percent from 1999 levels when fully implemented.[170]

Accordingly, with passage of the CAMR, those in the power-generation industry actively sought to reduce mercury emissions to the 70 percent limit such that their plants would be compliant when the reduction limits were fully implemented.

144. But even before the EPA officially passed the CAMR in 2005, the industry was put on notice of the upcoming rule. On December 15, 2003, the EPA signed proposed rules, and published them on January 30, 2004 in the Federal Register.[171] The EPA further explained that the "rules would significantly reduce emissions of sulfur dioxide (SO2), nitrogen oxides (NOx), and mercury from power plants," and explained that publication "in the Federal Register marks the beginning

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[168] Ex. 1055 (Clean Air Mercury Rule).
[169] Ex. 1055 (Clean Air Mercury Rule).
[170] Ex. 1056 (3/15/2005 EPA Press Release).
[171] Ex. 1009 (EPA-Proposal).

of a 60 day comment period" that included public hearings.[172] The proposed rules stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018."[173] The EPA again announced this "70 percent" reduction in mercury emissions on February 24, 2004, when it further sought public comment.[174] Accordingly, as of January 2004, if not earlier, the EPA put the power-generation industry on notice that upcoming regulations would require a 70% reduction in mercury emissions, and researchers actively sought processes that would achieve those limits.

F. DOE AND NETL

145. Since the early 1990s the National Energy Technology Laboratories ("NETL") of the U.S. Department of Energy ("DOE") has been carrying out a comprehensive R&D program to develop low-cost mercury control technologies for coal-fired power plants.[175] The NETL sponsored field-test programs at coal-fired power plants to characterize Hg emissions for the coals and plant configurations representing the American utility industry.[176] The NETL currently operates offices and test sites at three locations, Pittsburgh, PA, Morgantown, WV, and Albany, OR.

[172] Ex. 1057 (1/29/2004 EPA Press Release).
[173] Ex. 1009 (EPA-Proposal) at 4698.
[174] Ex. 1058 (2/24/2004 EPA Press Release).
[175] Ex. 1039 (Feeley) at 2.
[176] Ex. 1039 (Feeley) at 10-11.

146. Mercury-emissions control programs were managed from the Pittsburgh site. This site has a long and distinguished record in the inception and development of air pollution control for power plants, starting with early R&D on electrostatic precipitators in the 1960s, flue gas desulfurization units in the 1970s, and low-NO_x firing practices in the 1980s. The NETL was a major sponsor of the early demonstrations of the technologies that ultimately dominated markets for air pollution control devices ("APCDs"). It played a similarly important role in the demonstration of Hg control technologies, including inherent control with existing APCDs, activated carbon injection, both with and without halogens.[177]

G. WELL-KNOWN METHODS OF ENHANCING MERCURY REMOVAL USING ACTIVATED CARBON

147. Typical sorbents, including activated carbon, were known to have low native capacities for adsorbing mercury.[178] Traditional mercury sorbents were known to have capacities "on the order of 100 micrograms Hg/gram sorbent, and range from 10^{-6} to 10^{-2} gram Hg/gram sorbent."[179] However, researchers in 1998 also suggested that an activated carbon/mercury ratio between 3000:1 to 50,000 to 1 would be required to meet mercury removal demands.[180]

[177] Ex. 1039 (Feeley) at 10-11.
[178] Ex. 1038 (Granite) at 5.
[179] Ex. 1038 (Granite) at 5.
[180] Ex. 1038 (Granite) at 5.

148. Before 2003, researchers had worked to develop ways to increase activated carbon's sorption efficiency. In particular, researchers had found that "[o]ther compounds act as promoters for the removal of mercury from flue gas."[181] The term "promoter" was used to describe chemicals—including halides and halogens—that "increase the capacity of activated carbon."[182] A promoter was known to be "a chemical dispersed on or within a high surface area substrate, which aids in the removal of mercury from flue gas."[183] Specifically, promoters were known to "increase the chemisorption and chemical reaction of mercury on the sorbents."[184]

1. Alkali Promoters of Activated Carbon

149. An example of a well-known early promoter for activated-carbon sorbents was hydrated lime, calcium hydroxide [$Ca(OH)_2$].[185] Lime was known for its use "in conjunction with activated carbon in some commercial sorbent processes."[186] Researchers noted that "lime has been demonstrated to reduce mercury emissions in coal flue gas, even though lime neither sorbs nor reacts directly with mercury."[187] The researchers "speculated that lime aids in the removal of

[181] Ex. 1038 (Granite) at 5.
[182] Ex. 1038 (Granite) at 15.
[183] Ex. 1038 (Granite) at 15.
[184] Ex. 1038 (Granite) at 15.
[185] Ex. 1038 (Granite) at 15.
[186] Ex. 1038 (Granite) at 5.
[187] Ex. 1038 (Granite) at 5.

mercury by reacting with acid gases such as SO_2 that compete for adsorption with mercury on coal ash, unburned carbon particles, and activated-carbon sorbents."[188]

2. Halogen Promoters of Activated Carbon

150. By 1934, it was known in the art that halogens improved the ability of activated carbon to remove mercury. The Stock patent, issued in 1934, states:

> [I]t was found that in the process of purifying air vitiated with mercury vapors, adsorption agents which are impregnated with a halogen will constitute a protective agent, which is incomparably superior to any of the above mentioned protectives. For instance, active carbon impregnated with iodine will surpass the protective action of non-impregnated active carbon about ten times.[189]

By 1997, numerous studies had also been conducted that further described how halides interacted with mercury. For example, it was known that "halides are the most familiar compounds of mercury(I) and all contain the Hg_2^{2+} ion."[190] In particular, it was known that mercury could form HgF_2, $HgCl_2$, $HgBr_2$, HgI_2, Hg_2F_2, Hg_2Cl_2, Hg_2Br_2, and Hg_2I_2.[191] It was also known that solubility of HgX_2 compounds in water "decrease[s] with increasing molecular weight."[192] As such, it was known that Hg_2Br_2 was easier to precipitate out from an aqueous solution (e.g., in a scrubber), as compared to Hg_2Cl_2. And that Hg_2Cl_2 and $HgBr_2$ readily dissolve in aqueous scrubber solutions, whereas Hg^0 is insoluble.

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188 Ex. 1038 (Granite) at 5.
189 Ex. 1029 (Stock) at 1: 33-41.
190 Ex. 1041 (Greenwood) p. 1212.
191 Ex. 1041 (Greenwood) p. 1212-13.
192 Ex. 1041 (Greenwood) p. 1212.

151. It was well-known that halides, such as chlorine, "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[193] As such, it was known that the introduction of halogens helped remove mercury through at least two mechanisms: (1) by oxidizing the mercury, and thus rendering the mercury more susceptible to removal; (2) and by increasing the ability of the activated carbon to bind with the mercury. For each of these mechanisms, it was known that halogens improved mercury removal.

152. It was known that using halogens to oxidize mercury had the beneficial effect of increasing mercury removal in wet systems, because oxidized mercury is more soluble in water as compared to elemental mercury. For example, Vosteen (which discussed both wet processes and dry processes) compared "quasi-insoluble" elemental mercury to "ionic" (oxidized) mercury:

> At a high chlorine content the proportion of ionic mercury in the flue gas is high. Ionic mercury may be readily removed in scrubbers. The quasi-water-insoluble metallic mercury can be converted into ionic mercury, for example by adding oxidizing agents, such as peroxides, ozone or sodium chlorite, in the boiler exit gas upstream of the flue gas cleaning system or in the dedusted boiler gas, and then removed in the flue gas cleaning system as for example in scrubbers.[194]

[193] Ex. 1062 (Crocker) at 2-3.
[194] Ex. 1008 (Vosteen) at 1: 27-35.

Granite reported in 1998 that elemental mercury had a solubility in water of only 20 micrograms/liter at 68°F.[195] However, mercuric chloride ($HgCl_2$) had a solubility in water of 69 grams/liter and mercuric bromide (HBr_2) had a solubility in water of 6.1 grams/liter.[196] Both of these solubilities were over 5 orders of magnitude higher than the solubility of elemental mercury. Among these candidates, it was also known that "bromine compounds oxidize mercury more effectively under the given conditions of high-temperature processes" as compared to "chlorine compounds."[197]

153. It was also known in the art that adding halogens increased the effectiveness of dry-cleanup systems, such as activated-carbon sorbent, in removing mercury. Granite reported in 1998 that an "example of promoters are the halides and sulfides, which are often dispersed on high surface-area carbons and aluminosilicates."[198]

154. Some of the earlier DOE-NETL sponsored field tests on Hg emissions control monitored Hg capture efficiencies with untreated powdered-activated carbons (PAC) like Norit Darco FGD. These trials showed that the efficiencies increased in proportion to the chlorine:coal ratio, which prompted the understanding that adding chlorine to the PAC was an effective and inexpensive way to control Hg

[195] Ex. 1038 (Granite) at 11-12.
[196] Ex. 1038 (Granite) at 12-13.
[197] Ex. 1008 (Vosteen) at 4: 48-52.
[198] Ex. 1038 (Granite) at 5.

emissions with lower PAC injection rates and, therefore, at lower cost.[199] Moreover, it was known for nearly a century[200] that chlorine-containing gases, such as Cl_2 and HCl, could be bound to a wide variety of carbons simply by heating the chlorine-containing gas mixture together with the PAC to moderate temperatures. Consequently, the incentive and the basic production scheme for chlorinated PAC was easily surmised soon after the first trials on untreated PAC.

155. The EPA recognized such benefits of promoting activated carbon with halogens, and included the technology in its proposed mercury-reduction rules published in January 2004. By January 2004, the EPA said that two "types of sorbent that may be viable for use in sorbent injection include two basic types of activated carbon (AC; regular and impregnated)."[201] The EPA described chemically-impregnated AC as follows:

> Chemically-impregnated AC [activated carbon] is AC that has been supplemented with chemicals to improve its Hg removal. The Hg in the flue gas reacts with the chemical that is bound to the AC, and the resulting compound is removed by the PM [(particulate matter)] control device. Typical impregnants for AC are Cl, sulfur, and iodide. Chemically-impregnated AC have shown enhanced Hg removal over regular AC. Chemically-impregnated AC require smaller rates of carbon injection than does regular AC for equivalent Hg removals. The required carbon-to-mercury mass ratio may be reduced by a factor of from 3 to 10 with the chemically-impregnated AC. The cost per mass

[199] Ex. 1028 (Bustard).
[200] Ex. 1042 (Puri) at 255.
[201] Ex. 1009 (EPA-Proposal) at 4676.

> unit of impregnated AC may, however, be significantly greater than that of unmodified AC.[202]

156. As reflected in the EPA proposed rules, researchers had earlier recognized the benefits of promoting activated carbon with halogens and sulfur in terms of mercury removal:

> Activated carbons are the most studied mercury sorbents. Activated carbons have some serious drawbacks, including high cost, poor utilization/selectivity for mercury, and limited regenerability. Activated carbons are often promoted with halogens or sulfur to improve their ability to sorb elemental mercury. This improvement comes at a price; promoted activated carbons are three times more costly than unpromoted carbons.[203]

As such, it was known long before the earliest filing date of the Challenged Patent that promoting activated carbon with halogens, such as chlorine or iodine, were beneficial but with attendant costs. "In order for a sorbent to attain wide usage for mercury removal from flue gas, it must be highly active, selective, and cost effective."[204] Accordingly, researchers sought, and successfully demonstrated, more economic methods for promoting the activated carbon.

157. Once the superior performance of PACs with appreciable chlorine was demonstrated, a person of skill in the art would have realized that other halogens would exhibit the same or, hopefully, an even greater advantage. In contrast to

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[202] Ex. 1009 (EPA-Proposal) at 4676.
[203] Ex. 1038 (Granite) at 32.
[204] Ex. 1038 (Granite) at 6.

fluorine and astatine, a person of skill in the art had good reasons to expect that Hg-control efficiencies using bromine (Br) and iodine (I) were at least as good as chlorine's in activated-carbon applications. Indeed, as reflected by the EPA proposed rules discussed above, the EPA had recognized the benefits of both chlorine and iodine when used with activated carbon, and bromine sits between the two in the same group in the periodic table. A person of skill in the art would have further understood the applicability of bromine, because untreated PACs are known to be basic in their chemical character, whereas the halides of Cl, Br, and I were often referred to in the utility industry as "acid gases." A person of skill in the art, and anyone with a rudimentary understanding of chemistry, would have known that acids have a strong affinity for bases, and quickly surmise that Br and I would readily bind with PAC, because Cl and PAC behave like any combination of acids and bases.

158. Moreover, a person of skill in the art would have known that, like any carbon, PACs are not homogeneous materials whose reactivities are determined by a single configuration of atoms on the surface. Rather, it was known that their most reactive "sites" are the atoms at the edges and in defects on large sheets of atoms that constitute the bulk of PAC structure. The edge sites contain unpaired electrons that impart the basic character (i.e., ability to donate electrons and thus act as Lewis bases) to PAC and have the strongest affinity for protons when acid gases contact the carbon. A person of skill in the art would have considered bond-dissociation

energy as a relevant molecular characteristic when evaluating halogens for Hg control with activated-carbon injection. It was known that the dissociation energies are 428 kJ/mol for HCl, 363 for HBr, and 294 for HI.[205] Based on these values a POSITA would expect Br and I to have an even greater affinity for PAC than Cl, because it takes less energy to form the ions of Br and I than those of Cl.

159. In addition to the reaction between acid gases and activated carbon, a person of skill in the art would have known that mercury-bromide compounds stick more effectively to activated carbon than mercury-chloride compounds, and thus are more effectively removed. "Mercury bromide $HgBr_2$ adsorbs more strongly to dry sorbents than mercury chloride $HgCl_2$."[206]

160. For these reasons, a person of skill in the art would have known, and would have been motivated to try, other forms of halogens for mercury removal, beyond chlorine. Such a person would have known that binding Br and I to activated carbon has the potential to improve Hg capture efficiencies in activated-carbon injection applications, and that the same process used to make chlorinated activated carbon would have likely worked with Br and I in gas mixtures. Several researchers prior to the earliest filing date of the Challenged Patent had tried both chlorine and bromine, and found bromine to be more effective.

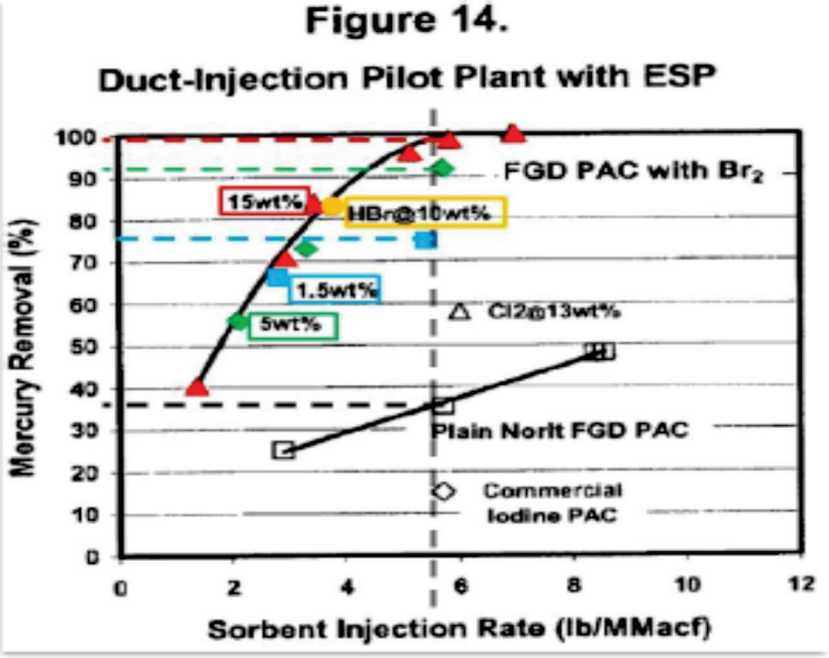
[205] Ex. 1041 (Greenwood) at 804.
[206] Ex. 1008 (Vosteen) at 5: 36-39.

161. By 2003, Vosteen Consulting GmbH had also conducted "experiments to demonstrate the effect of bromine on mercury removal in a coal-fired power station of Bayer AG in Uerdingen."[207] In particular, "an experiment was carried out with addition of aqueous $HgCl_2$ solution and aqueous NaBr solution into the combustion chamber to demonstrate the effect of bromine on Hg oxidation."[208] The results of these experiments are shown in Figures 7 and 8 of Vosteen.[209]

162. In addition to Vosteen, other prior-art researchers had succeeded in providing methods for a more cost-effective, activated carbon for mercury removal. Other researchers filed patent applications and published articles for using bromine-containing promoters to improve the effectiveness of activated carbon in capturing both elemental and oxidized mercury.[210] Nelson recognized in a patent dating back to at least May 2003 that chlorinated PAC improved mercury capture, as compared to untreated PAC, but that brominated PAC improved mercury capture even more.[211] Nelson provided his results in Figure 14, annotated below, showing sorbent injection with differing amounts of halogens added.

[207] Ex. 1008 (Vosteen) at 10: 64-66.
[208] Ex. 1008 (Vosteen) at 10: 67-11: 3.
[209] Ex. 1008 (Vosteen) at 10: 64-12: 14, Figure 7, Figure 8.
[210] Ex. 1006 (Downs-Boiler); Ex. 1008 (Vosteen); Ex. 1010 (Sjostrom); Ex. 1011 (Eckberg); Ex. 1012 (Nelson); Ex. 1015 (Downs-Halogenation); Ex. 1036 (Lissianski).
[211] Ex. 1012 (Nelson) at Figure 14 (annotated).

Figure 14.



In the annotated figure, points with a similar halogen loading are colored the same. Nelson provided data for a sorbent injection rate of approximately 5.8 pounds per million actual cubic feet (lb/MMacf), indicated by the vertical dashed black line. Nelson indicated that at this sorbent injection rate, untreated activated carbon ("Plain Norit FGD PAC") was able to remove less than 40% mercury. In contrast, adding 13 wt% chlorine via Cl_2 to the activated carbon (indicated by the Δ on the graph) was able to remove close to 60% mercury. Nelson was able to achieve mercury removal greater than 70% at the same activated-carbon sorbent injection rate by applying bromine (Br_2) gas. Nelson achieved: 75% mercury removal by loading the activated carbon with 1.5 wt% bromine (indicated by the ■); approximately 92% mercury removal by loading the activated carbon with 5 wt% bromine (indicated by the ♦); and near 100% mercury removal by loading the activated carbon with 15 wt

% bromine (indicated by the ▲).[212] When using hydrogen bromide (HBr) gas to load the activated carbon with 10 wt% bromine (indicated by the ●), Nelson achieved approximately 85% mercury removal with a lower sorbent injection rate of 3.7 lb/MMacf.

163. Accordingly, Nelson and other researchers had recognized the desirability of adding bromine to activated carbon for purposes of mercury removal and various processes to accomplish the bromine promotion. Researchers had also figured out, and filed patents on, multiple other ways to promote the activated carbon with bromine, including by:

- providing a bromine-containing promoter separately from the activated carbon directly into the mercury-containing flue gas, as in Lissianski,[213]
- injecting activated carbon directly into the flue gas, and adding a bromine-containing promoter into either the combustion chamber and/or onto the coal, as in Vosteen[214] or Downs-Boiler.[215]

H. PYROLYSIS CHAR

164. Pyrolysis char is a commercially important commodity sold as coke for steelmaking and as briquettes for household cooking throughout the developing countries. It is also a raw feedstock for activated carbons, including products such

[212] Ex. 1012 (Nelson) at Figure 14, 8: 35-53.
[213] Ex. 1036 (Lissianski).
[214] Ex. 1008 (Vosteen).
[215] Ex. 1006 (Downs-Boiler).

as Darco FGD from Norit Americas that are used for Hg emissions control. Pyrolysis char inevitably forms whenever any coal is heated above about 400 °C, which occurs in every technology for coal utilization, including coal-fired power plants.

165. All of the asserted claims of the ’225 patent concern, among other elements, pyrolysis char. Those claims entail combusting a mixture comprising coal, pyrolysis char, and a bromine additive. The ’225 patent does not stipulate that the combustible mixture include coal-derived pyrolysis char so any commercial pyrolysis char in the mixture meets the stipulation in the claims.

166. Pyrolysis char is a product of a spontaneous chemical process called pyrolysis or devolatilization.[216] Pyrolysis partitions the coal into a complex mixture of gases called “volatiles” and a solid residue called “char.” With most coal types char comprises about half the coal mass, nearly all coal minerals, and most of the carbon in the coal, but relatively little of the oxygen, sulfur, and hydrogen. However, char yields with lignite are only about one-third the coal mass and with low volatility coals, the yields can exceed 90 %. Char forms with or without O_2 or any other reactive gas. In furnaces, pyrolysis is complete within 200 to 300 ms after the coal is injected, so pyrolysis char is present within the burner belts or coal injector elevations. As it moves through the furnace and contacts O_2, it ignites to

[216] [NE1] S. Niksa, G.-S. Liu, and R. H. Hurt. Coal conversion submodels for design applications at elevated pressures. Part I. Devolatilization and char oxidation. Prog. Energy Combust. Sci., 29(5):425-477 (2003).

temperatures as hot as 2000 °C and is oxidized into CO_2 plus minor amounts of H2O, CO, SO_2, and NO.

167. The very small amounts of char that leave through a furnace exit and move through a gas cleaning system are collected in PCDs with flyash and called UBC. However, pyrolysis char and UBC have grossly different characteristics. Due to the exposure to very hot temperatures upon ignition in the furnace, UBC anneals into more crystalline forms and is much less reactive than pyrolysis char.[217]

168. The spontaneous production of pyrolysis char in furnaces was exploited by Pennline et al. for Hg emissions control.[218] In their "Thief Process" pyrolysis char is withdrawn from the near-burner flame zone of a furnace, separated from the combustion gases and, perhaps, treated with chemicals or thermal conditioning. The char is then re-injected into the gas cleaning system to adsorb Hg from the flue gas as a raw or promoted PAC sorbent, and recovered in a downstream PCD with fly ash.

XIII. OVERVIEW OF THE CHALLENGED PATENT FAMILY

A. FAMILY TREE

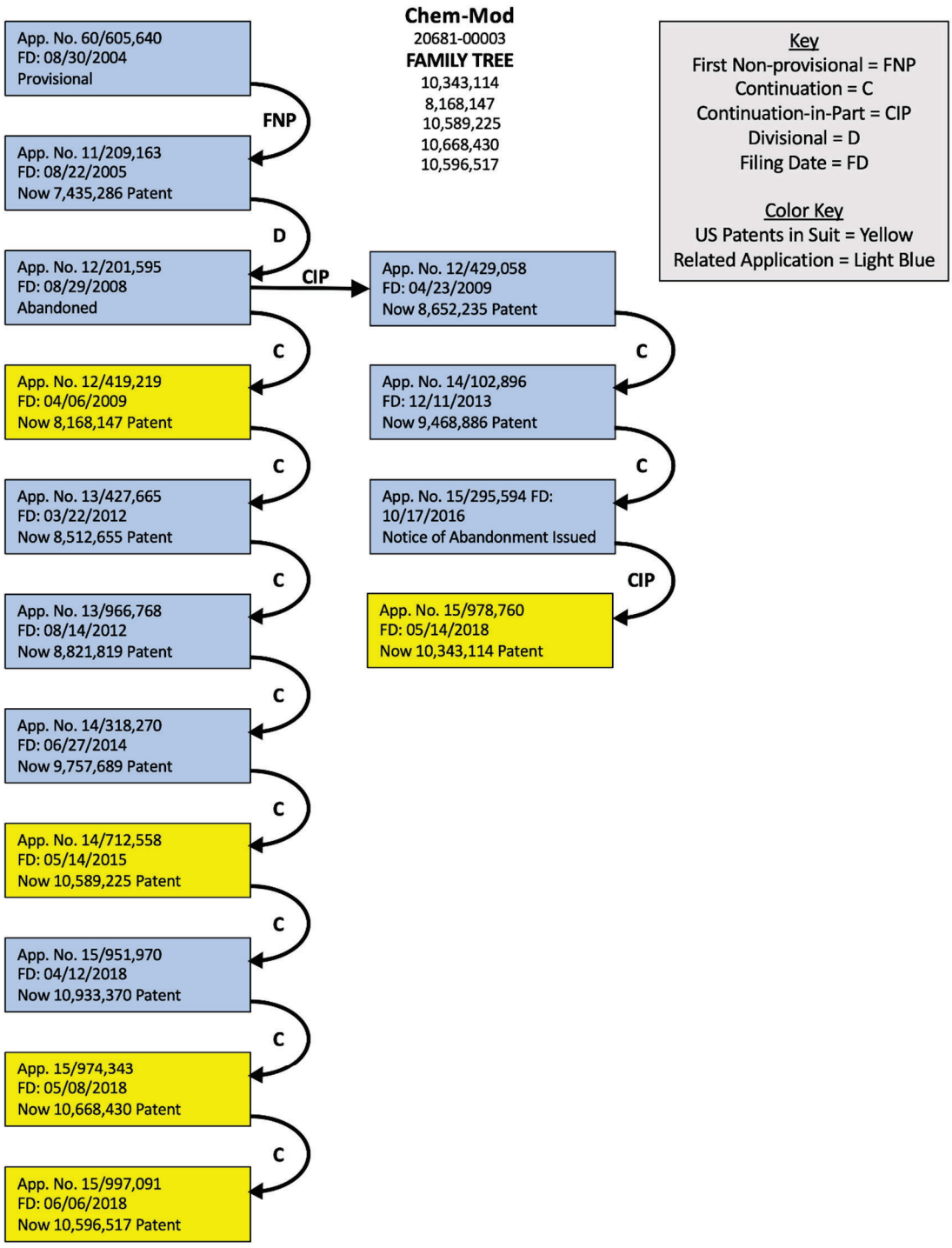
169. The application that led to the '147 Patent was filed on April 6, 2009, and was the first application filed out of the applications that led to the five Asserted

[217] [NE2] Robert H. Hurt, Kevin A. Davis, Nancy Y. C. Yang, Thomas J. Headley, Gareth D. Mitchell. Residual carbon from pulverized-coal-fired boilers 2. Morphology and physicochemical properties. Fuel 74(9):1297-1306 (1995).
[218] [NE3] US Patent No. 6,521,021 B1

Patents. The applications that led to the '225 Patent was filed on May 14, 2015; the applications that led to the remaining three patents were filed in 2018.

170. I understand that the family tree below depicts the Asserted Patents, and the patent applications to which each of them claim priority.[219]

[219] Ex. 2015 (Family Tree).


Chem-Mod
20681-00003
FAMILY TREE
10,343,114
8,168,147
10,589,225
10,668,430
10,596,517
Key
First Non-provisional = FNP
Continuation = C
Continuation-in-Part = CIP
Divisional = D
Filing Date = FD
Color Key
US Patents in Suit = Yellow
Related Application = Light Blue
App. No. 60/605,640
FD: 08/30/2004
Provisional
FNP
App. No. 11/209,163
FD: 08/22/2005
Now 7,435,286 Patent
D
App. No. 12/201,595
FD: 08/29/2008
Abandoned
CIP
App. No. 12/429,058
FD: 04/23/2009
Now 8,652,235 Patent
C
App. No. 12/419,219
FD: 04/06/2009
Now 8,168,147 Patent
C
App. No. 14/102,896
FD: 12/11/2013
Now 9,468,886 Patent
C
App. No. 13/427,665
FD: 03/22/2012
Now 8,512,655 Patent
C
App. No. 15/295,594 FD: 10/17/2016
Notice of Abandonment Issued
CIP
App. No. 13/966,768
FD: 08/14/2012
Now 8,821,819 Patent
App. No. 15/978,760
FD: 05/14/2018
Now 10,343,114 Patent
C
App. No. 14/318,270
FD: 06/27/2014
Now 9,757,689 Patent
C
App. No. 14/712,558
FD: 05/14/2015
Now 10,589,225 Patent
C
App. No. 15/951,970
FD: 04/12/2018
Now 10,933,370 Patent
C
App. 15/974,343
FD: 05/08/2018
Now 10,668,430 Patent
C
App. No. 15/997,091
FD: 06/06/2018
Now 10,596,517 Patent

171. The application data sheets (ADS) of each of the five patents claim priority from the abandoned 12/201,595 application (the "'595 Application").[220] , which is a divisional application of the 11/209,163 application (now the 7,435,286 patent), which claims priority from the 60/605,640 provisional application (the "Provisional").[221] At this point, the priority chain diverges. The '114 patent is a continuation-in-part which claims priority from the 15/295,594 application, which is a continuation of the 14/102,896 application (now the 9,468,886 patent), which is a continuation of the 12/429,058 application (now the 8,652,235 patent), which is a continuation-in-part of the 12/201,595 divisional application.

172. On the other hand, the '517 patent is a continuation, which claims priority from the '430 patent (once the 15/974,343 application), which is a continuation of the 15/951,970 application (now the 10,933,370 patent), which is a continuation of the '225 patent (once the 14/712,558 application), which is a continuation of the 14/318,270 application (now the 9,757,689 patent), which is a continuation of the 13/966,768 application (now the 8,821,819 patent), which is a continuation of the 13/427,665 application (now the 8,512,655 patent), which is a continuation of the '147 patent (once the 12/419,219 application), which is a continuation of the 12/201,595 divisional application.

[220] Ex. 1022 ('595 Application File History) at exhibit pages 1-46.
[221] Ex. 1020 (Provisional).

B. SPECIFICATION OF THE ASSERTED PATENT FAMILY

173. The specifications of the '147, '225, '430 and '517 Patents are all substantially the same. According to the common specification, the invention "relates to methods and materials for the removal of pollutants from flue gas or product gas from a gasification system."[222] The specification discloses that "mercury is removed from gas streams generated during the burning or gasification of fossil fuels by highly reactive regenerable sorbents."[223]

174. The specification admits that known "mercury control methods" included "injection of fine sorbent particles into a flue gas duct" such as "activated carbon."[224] However, the specification acknowledged that "[a] major problem with existing carbon injection systems is that the sorbent is relatively unreactive toward mercury" and therefore "must be used in large amounts, at high sorbent-to-mercury ratios, to effectively capture the mercury."[225] The specification acknowledges this is a problem because activated carbon is "relatively expensive and cannot be easily separated from the ash for regeneration and reuse."[226]

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222 Ex. 1001 ('147 Patent) at 1:29-31.
223 Ex. 1001 ('147 Patent) at 1:31-33.
224 Ex. 1001 ('147 Patent) at 1:57-61.
225 Ex. 1001 ('147 Patent) at 2:10-16.
226 Ex. 1001 ('147 Patent) at 2:16-18.

175. The specification purports to "provide[] a cost-effective way to capture pollutants by utilizing exceptionally reactive halogen/halide promoted carbon sorbents using a bromide (or other halogen/halide) treatment of the carbon, that capture mercury via mercury-sorbent surface reactions."[227] Fig. 2 of the all of the Asserted Patents is the same, and describes a "theory developed from scientific evidence to explain the nature of the promoting compounds."[228]

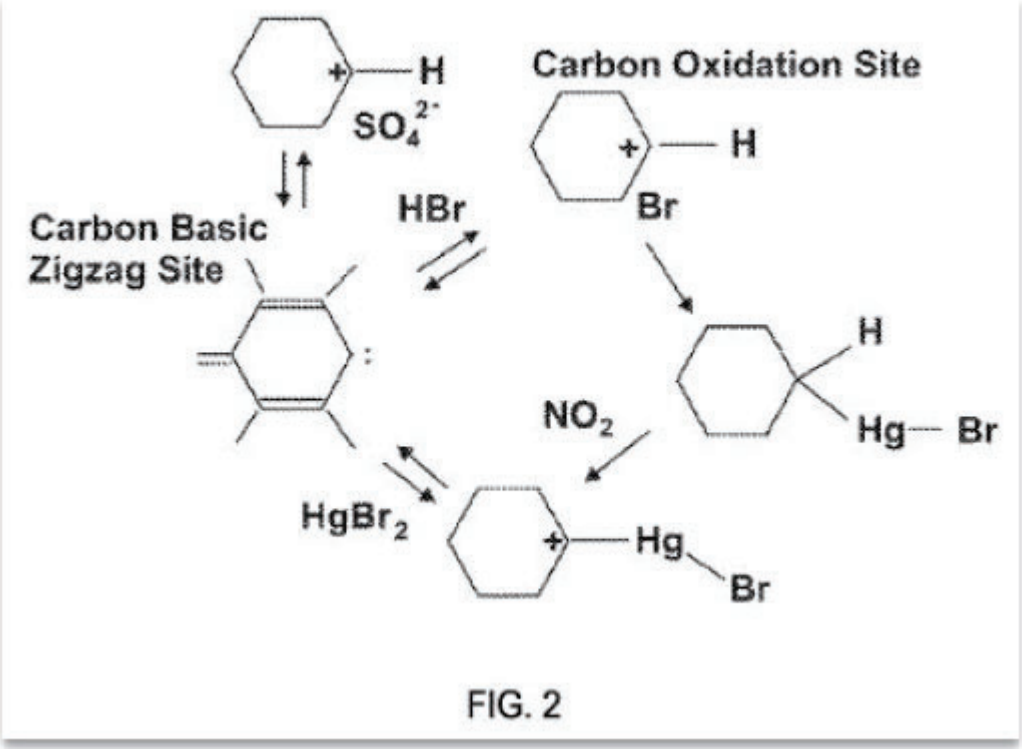


FIG. 2

Fig. 2 shows that "hydrogen bromide reacts with the unsaturated structure of the activated carbon," and this may occur at "a carbene species on the edge of the graphene sheets structures of the carbon."[229] The '147 Patent explains that

[227] Ex. 1001 ('147 Patent) at 6:19-23.
[228] Ex. 1001 ('147 Patent) at 7:61-63, Fig. 2.
[229] Ex. 1001 ('147 Patent) at 7:61-67.

"[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury."[230]

176. Fig. 1 of the '147 Patent is "a block flow diagram illustrating some preferred embodiments of the process of the present invention to prepare promoted sorbents useful for mercury capture from flue gas and/or product gas form a gasification system streams."[231]

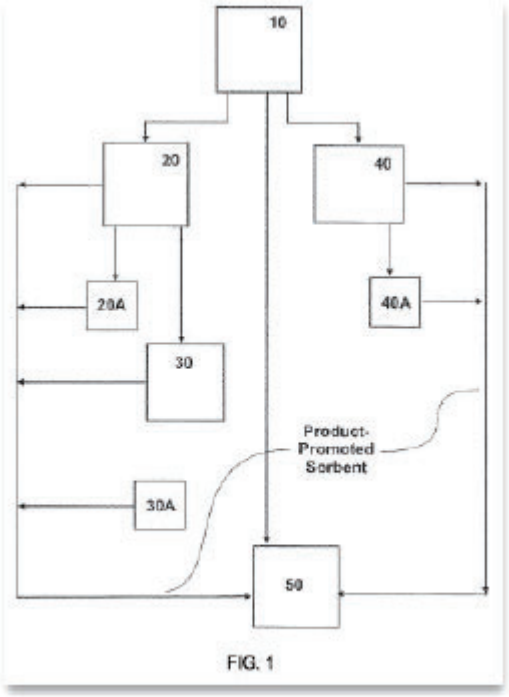


FIG. 1

The specification details several embodiments for adding the base activated carbon to a flue gas stream. Specifically, the specification describes a first embodiment wherein "block 10 illustrates providing a base activated carbon, and adding a halogen or halide promoter that reacts with the carbon, illustrated at block 20, to

[230] Ex. 1001 ('147 Patent) at 7:67- 8:1-2.
[231] Ex. 1001 ('147 Patent) at 6:40-44, Fig. 1.

produce a product promoted carbon sorbent."[232] As an addition to this embodiment, the specification contemplates "providing a base activated carbon as shown by block 10, adding a halogen or halide promoter that reacts with the carbon, illustrated at block 20, and adding a secondary component illustrated at block 30 that reacts with the result of block 20 to produce a promoted carbon sorbent."[233] The specification also describes a second embodiment that includes "providing a base activated carbon as illustrated at block 10, and adding a halogen or halide promoter and a secondary component to the activated carbon together, with which they react as illustrated by block 40."[234] For all embodiments, the specification explains that any promotion of activated carbon occurs prior to injection of the promoted brominated carbon into the flue gas—"as illustrated by block 50, a flue gas stream is treated with product promoted carbon sorbent prepared as described above."[235]

177. One difference between the specification of the '517 and '430 Patents as compared to the '147 and '225 Patents is that the '517 and '430 Patents have an additional figure (Figure 11) that the earlier filed '147 and '225 Patents do not have. I discuss this figure in the priority date analysis below.

178. The '114 patent is related to the other asserted patents through a continuation-in-part branch. I have been informed that a "continuation-in-part" application is

[232] Ex. 1001 ('147 Patent) at 6:45-48.
[233] Ex. 1001 ('147 Patent) at 6:56-61.
[234] Ex. 1001 ('147 Patent) at 7:3-6.
[235] Ex. 1001 ('147 Patent) at 7:13-15.

a type of patent application that is filed during the lifetime of an earlier nonprovisional application, repeating some substantial portion or all of the earlier nonprovisional application and adding matter not disclosed in the earlier nonprovisional application.

179. The continuation-in-part application that ultimately issued as the '114 Patent was filed on May 14, 2018 as U.S. Patent Application No. 15/978,760 (the "'760 Application").

180. When the applicants filed the '760 Application on May 14, 2018, they repeated a substantial portion of the '594 Application, but then added matter not disclosed in the '594 Application. Attached as Exhibit 1068 is a redline comparison between the '594 Application and the '760 Application. I understand that the redline was prepared by using the '594 Application as the starting document, and then showing what was changed with the filing of the '760 Application.[236] As can be seen, substantial modification of the specification was made, and I refer to these changes below. Among other changes that were made when filing the '760 Application, the applicants copied and pasted Figure 2 and surrounding text from the Provisional.[237] The applicants renumbered Figure 2 of the Provisional as Figure 6 of the '760 Application.

[236] Ex. 1068 (Redline Comparison, showing changes from '594 Application (as published at 2017/0128908) to '760 Application (as published at 2018/0257031)).

[237] Ex. 1001 ('114 Patent) at 21: 33-33: 3, Figure 6; see also Ex. 1067 (Redline Comparison, Showing changes from the Provisional (excerpted from Ex. 1020) to '760 Application (as published at 2018/0257031)).

C. SUMMARY OF PATENT PROSECUTIONS

1. Filing of the '147 Patent

181. On April 6, 2009, on the day of filing the '219 Application, the applicants submitted a preliminary amendment cancelling claims 1 through 33 and adding new claims 34 through 57.[238] Claims 34 through 57 focused on the use of a halogenated promotor to aid mercury capture.[239] Within these newly introduced claims were included application claims 53 and 54, which ultimately issued as claims 17 and 18 of the '147 Patent. Claims 17 and 18 of the '147 Patent, which have not changed since they were filed as claims 53 and 54 in the '219 Application, recite:

> 17. A method according to claim 1, further comprising injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into a gas stream whereby in-flight reaction produces the promoted brominated sorbent, wherein the promoter is reacted in the gas phase or as a vapor, wherein the promoter is added at from about 1 to about 30 grams per 100 grams of the sorbent material.
>
> 18. A method according to claim 17, wherein the gas stream is a mercury containing gas.[240]

[238] Ex. 1019 ('147 Patent File History) at exhibit page 55.
[239] Ex. 1019 ('147 Patent File History) at exhibit pages 55-58.
[240] Ex. 1001 ('147 Patent) at claims 17, 18; Ex. 1019 ('147 Patent File History) at exhibit page 57.

After the initial filing, the USPTO issued a Notice to File Corrected Application Papers on September 4, 2009.[241] This notice requested corrections to Figures 2 and 4-10 of the '219 Application.[242]

The required item(s) identified below must be timely submitted to avoid abandonment:

- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121(d) are required. The drawings submitted are not acceptable because:
  - The drawings have a line quality that is too light to be reproduced (weight of all lines and letters must be heavy enough to permit adequate reproduction) or text that is illegible (reference characters, sheet numbers, and view numbers must be plain and legible) see 37 CFR 1.84(l) and (p)(1)); See Figure(s) 2, 4-10.
  - Numbers, letters, and reference characters on the drawings must measure at least 0.32 cm (1/8 inch) in height. See Figure(s) 3-10.

On November 4, 2009, the applicant filed a complete replacement set of all Figures—including a replacement of Figure 1 ("Replacement-Figure 1") —that was not requested for replacement by USPTO in its September 4, 2009 Notice to File Corrected Application Papers.[243] These preliminary amendments and replacement drawings are discussed in greater detail below.

2. '147 'Subsequent Prosecution History

182. On January 15, 2010, the examiner issued a non-final rejection of all pending claims as anticipated or obvious over various combinations among U.S. Patent No. 6,848,374 to Srinivasachar alone, and in combination with other references.[244] On July 15, 2010, the applicant filed a response to the non-final rejection narrowing the claims by amending them to require a brominated

[241] Ex. 1019 ('147 Patent File History) at exhibit page 69.
[242] Ex. 1019 ('147 Patent File History) at exhibit page 69.
[243] Ex. 1019 ('147 Patent File History) at exhibit pages 71-81.
[244] Ex. 1019 ('147 Patent File History) at exhibit pages 216-28.

promoter, rather than simply a halogenated promoter.[245] The edits to application claim 34 (which ultimately issued as '147 Patent claim 1) are shown below:[246]

34. (Currently Amended) A method for separating mercury from a mercury containing gas comprising:

~~(a) providing a sorbent material;~~

~~(b) providing a halogen or halide promoter;~~

~~(c)~~ (a) promoting at least a portion of ~~the~~ a sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing ~~the halogen or halide~~ promoter to form a promoted ~~halogenated~~ brominated sorbent, wherein the bromine containing promoter is in gaseous form, vapor form, or non-aqueous liquid form;

~~(d)~~ (b) chemically reacting elemental mercury in the mercury containing gas with the promoted ~~halogenated~~ brominated sorbent to form a mercury/sorbent chemical composition; and

~~(e)~~ (c) separating particulates from the mercury containing gas, the particulates including ash and the mercury/sorbent chemical composition.

The applicants explained, "Claim 34 is amended to characterize the promoter as a bromine containing promoter."[247] The applicants also amended dependent claim 38 as follows[248]:

38. (Currently Amended) A method according to claim 34, wherein the ~~sorbent material comprises base~~ activated carbon ~~that~~ contains basic binding sites which react with the bromine containing promoter to form a carbocation paired with a bromide anion ~~halogens, hydrohalides, and Group V and Group 6 halides to form highly reactive acidic binding sites~~ in the promoted brominated sorbent for oxidation of the mercury.

[245] Ex. 1019 ('147 Patent File History) at exhibit pages 255-58.
[246] Ex. 1019 ('147 Patent File History) at exhibit pages 255.
[247] Ex. 1019 ('147 Patent File History) at exhibit page 259.
[248]

The applicants then argued that Srinivasachar "simply provide[s] for depositing a halogen on the surface of the sorbent particles contacted by an oxidizing agent" and does not "take steps to provide a reaction product resulting from a reaction of a bromide containing promoter and activated carbon according to the presently claimed invention."[249]

183. On October 8, 2010, the applicants participated in an interview with the Examiner to discuss the rejection under the Srinivasachar reference. During that call, the applicants explained that their invention differs from Srinivasachar, in that "there is a carbo cation created to remove elemental mercury from the flue gas .."[250] The Examiner proposed that the claims would be allowed on account of the carbocation limitation:

> The examiner further explained that by combining the claim language of claim 38 with independent claim 34, this would overcome the Srinivasachar et al. reference because the Srinivasachar et al. reference does not disclose "the activated carbon contains basic binding sites which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury. The applicant authorized a claim amendment to claim 34 to include the content of claim 38 if claim 38 were to be found allowable.[251]

Ex. 1019 ('147 Patent File History) at exhibit pages 255-56.

250 Ex. 1019 ('147 Patent File History) at exhibit page 262.

250 Ex. 1019 ('147 Patent File History) at exhibit page 286.

251 Ex. 1019 ('147 Patent File History) at exhibit page 286.

184. On October 14, 2010, the examiner issued a final rejection of all pending claims.[252] The Examiner found that application claims 34, 35, 38-40, 49-52, and 58-60 were anticipated by U.S. Patent App. Pub. No. 2004/0003716 by Nelson (the "Nelson-Publication," Exhibit 1013)[253]. The remaining claims were obvious over Nelson-Publication in view of U.S. Patent No. 6,848,374 to Srinivasachar *et al.,* U.S. Patent No. 4,500,327 to Nishino *et al.,* Canadian Patent No. 1,099,490 to Jong, U.S. Patent No. 6,136,749 to Gadkaree *et al.,* and/or U.S. Patent No. 6,878,358 to Vosteen *et al*.[254] Regarding application claims 53-55 (which ultimately issued as claims 17-19 of the '147 Patent), the Examiner held that Nelson "does not disclose injecting the sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into a gas stream whereby in-flight reaction produces the promoted brominated sorbent, the gas stream is a mercury containing gas and the gas stream is a transport gas."[255] However, the Examiner held the following regarding obviousness of these claims:

> It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the 716 reference [Nelson-Publication] to include the sorbent material at an sorbent material injection rate and injecting separately the bromine containing promoter into a gas stream whereby in-flight reaction produces the promoted brominated sorbent (374,

[252] Ex. 1019 ('147 Patent File History) at exhibit pages 287-98.
[253] Ex. 1019 ('147 Patent File History) at exhibit page 287.
[254] Ex. 1019 ('147 Patent File History) at exhibit pages 289-97.
[255] Ex. 1019 ('147 Patent File History) at exhibit page 293.

columns 5-6, lines 59-18), the gas stream is a mercury containing gas (374 columns 5-6 lines 55-18) and the gas stream being a transport gas (374, columns 5-6, lines 55-18).[256]

185. On February 15, 2011, the applicant filed a request for continued examination, amending the only pending independent claim (claim 34, which ultimately issued as claim 1) as highlighted below[257]:

> 34. (Currently Amended) A method for separating mercury from a mercury containing gas comprising:
>
> (a) promoting at least a portion of a sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter to form a promoted brominated sorbent, wherein the bromine containing promoter is in gaseous form, vapor form, or non-aqueous liquid form, and wherein the activated carbon contains graphene sheets having carbene species edge sites which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury;
>
> (b) chemically reacting elemental mercury in the mercury containing gas with the promoted brominated sorbent to form a mercury/sorbent chemical composition; and
>
> (c) separating particulates from the mercury containing gas, the particulates including ash and the mercury/sorbent chemical composition.

In its response, the applicant attempted to distinguish the amended claim from the Nelson-Publication the primary reference used in the final rejection—by arguing that Nelson-Publication "fails to disclose activated carbon containing graphene sheets having carbene species edge sites therein" and also "fails to disclose reacting a bromine containing promoter with activated carbon containing carbene species edge

[256] Ex. 1019 ('147 Patent File History) at exhibit page 294.
[257] Ex. 1019 ('147 Patent File History) at exhibit pages 319, 321-25.

sites to form a carbocation paired with a bromide anion in a promoted brominated sorbent according to the presently claimed method for separating mercury from a mercury containing gas."[258]

186. In response to multiple later rounds of rejections from the USPTO examiner, the applicants repeatedly sought to distinguish prior art based on the absence of graphene sheets with carbene edge sites.[259] On January 10, 2012, the examiner issued a notice of allowance, noting in the reasons for allowance the portions of issued claim 1 of the '147 Patent that contain the limitations added by amendment, as highlighted below:[260]

2. The following is an examiner's statement of reasons for allowance: a method for separating mercury from a mercury containing gas comprising promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter to form a promoted brominated sorbent, wherein the activated carbon contains grapheme sheets having carbine species edge sites which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury could not be found within the prior art.

[258] Ex. 1019 ('147 Patent File History) at exhibit page 327.
[259] Ex. 1019 ('147 Patent File History) at exhibit pages 390-404, 444-55
[260] Ex. 1019 ('147 Patent File History) at exhibit pages 466-72.

1. Filing of the '114 Patent

187. As originally filed, the '760 Application on May 14, 2018 included 1 claim and 7 drawings (Figures 1-4, 5A, 5B, 6, and 7).[261] As filed, claim 1 of the '760 Application is reproduced below:[262]

> 1. A method for separating mercury from a mercury and ash containing gas comprising:
>
> chemically reacting at least a portion of a carbon sorbent material and at least a portion of a non-carbon sorbent material with a halogen or a halide promoter to form a promoted halogenated carbon sorbent and a promoted halogenated non-carbon sorbent;
>
> chemically reacting elemental mercury in the mercury containing gas with the promoted halogenated carbon sorbent and the promoted halogenated non-carbon sorbent to form a mercury/sorbent chemical composition; and
>
> separating particulates from the mercury containing gas to form a cleaned gas, the particulates including ash and the mercury/sorbent chemical composition.

[261] Ex. 1026 ('114 Patent File History) at 10-62.
[262] Ex. 1026 ('114 Patent File History) at 55.

188. On May 15, 2018, the day after filing the '760 Application, a preliminary amendment was submitted that canceled Claim 1 and added new Claims 2 through 21.[263] Representative Claims 2, 6, and 7 are reproduced below as emphasized:[264]

2. (New) A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising Br_2, HBr, Br^-, or a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

reacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.

6. (New) The method of claim 2, wherein the combustion chamber comprises the halogen or halide promoter.

7. (New) The method of claim 2, wherein a promoter precursor is on the coal, wherein the combusting of the coal forms the halogen or halide promoter in the mercury-containing gas.

[263] Ex. 1026 ('114 Patent File History) at exhibit pages 74-80 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

[264] Ex. 1026 ('114 Patent File History) at exhibit pages 75 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

Claims 3 through 19 all depended from Claim 2.[265] The other independent claim, Claim 20, also recited "wherein the promoter comprises Br_2, HBr, Br^-, or a combination thereof."[266]

20. (New) A method for separating mercury from a mercury-containing gas, the method comprising:

reacting mercury in a mercury-containing gas with an injected in-flight promoted activated carbon sorbent to form a mercury/sorbent composition, wherein the promoter comprises Br_2, HBr, Br^-, or a combination thereof;

separating the mercury/sorbent composition from the mercury-containing gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level, wherein the method removes greater than 70 wt% of the mercury in the mercury-containing gas.

21. (New) The method of claim 20, wherein reacting the mercury in the mercury-containing gas with the promoted halogenated activated carbon sorbent to form the mercury/sorbent composition comprises reacting the mercury in the mercury-containing gas with the promoted halogenated activated carbon sorbent and with a promoted halogenated non-carbon sorbent to form the mercury/sorbent composition

At this point in the prosecution history, the independent claims did not require any particular type of bromine-containing species added to either the coal or to the combustion chamber, and at best used general terms such as "halogen or halide promoter" (claim 6) or "promoter precursor is on the coal" (claim 7). Through subsequent amendments, the applicants introduced limitations into the independent claims relating to adding specific types of bromine-containing species to either the

[265] Ex. 1026 ('114 Patent File History) at exhibit pages 75-79 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

[266] Ex. 1026 ('114 Patent File History) at exhibit page 78 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

coal itself or to the combustion chamber that were ultimately included in each of the independent claims of the ’114 Patent.

2. ’114 Subsequent Prosecution History

189. On June 29, 2018, the examiner found claims 2-19 allowable, but issued a non-final rejection of only application claims 20-21.[267] Claim 20 was rejected as being obvious over a combination of U.S. Patent App. Pub. No. 2004/0003716 by Nelson (the “Nelson Publication”)[268] in view of U.S. Patent No. 6,878,358 to Vosteen *et* al.[269] Claim 21 was rejected as being obvious over a combination of the Nelson Publication in view of Vosteen and further in view of U.S. Patent App. Pub. No. 2007/0168213 by Comrie.[270] With regard to Vosteen, the Examiner relied on the reference solely for purposes of disclosing the features of claims 20 and 21 that related to “monitoring the mercury content of the cleaned gas” for controlling the “injection rate of injecting the sorbent, . . . the sorbent composition, or a combination thereof.”[271] The Examiner found regarding Vosteen:

> The Vosteen et al. reference discloses monitoring the mercury content of the cleaned gas; and controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the

[267] Ex. 1026 (’114 Patent File History) at exhibit pages 1527-34 (’114 Patent File History, 6/29/2018 Office Action).
[268] Ex. 1013 (Nelson Publication).
[269] Ex. 1026 (114 Patent File History) at exhibit pages 1530-31 (114 Patent File History, 6/29/2018 Office Action).
[270] Ex. 1026 (’114 Patent File History) at exhibit page 1531 (6/29/2018 Office Action).
[271] Ex. 1026 (’114 Patent File History) at exhibit pages 1530-31 (6/29/2018 Office Action).

> sorbent composition, or a combination thereof (column 5, lines 47-63).
>
> * * *
>
> The Vosteen reference clearly shows that complete removal of the mercury in the mercury-containing gas (i.e. greater than 70% closer to 100% is desired) and is desired and obtainable by adding more adsorbent.[272]

The Examiner relied on the Nelson Publication and Comrie (U.S. Patent App. Pub. No. 2007/0168213) to disclose the remaining claim limitations.[273] In that same June 29, 2018 office action the examiner found claims 2-19 allowable.[274] However, the Examiner did not take a position as to whether or not either of the Nelson Publication or Vosteen disclosed these limitations. Throughout subsequent prosecution of the '114 Patent, Vosteen was not applied again by the Examiner.

190. On July 13, 2018, the applicant filed a response to the non-final rejection cancelling claims 20 and 21.[275] On October 10, 2018, the Examiner issued a non-final rejection withdrawing the statement of allowability regarding claims 2-19. The Examiner rejected all pending claims (claims 2-19) as obvious over a combination of U.S. Patent No. 5,435,980 to Felsvang (as the primary reference) and the Nelson Publication (as a secondary reference).[276] The Examiner found that Felsvang disclosed almost all the limitations from claims 2-19, including

[272] Ex. 1026 ('114 Patent File History) at exhibit pages 1530-31 (6/29/2018 Office Action).
[273] Ex. 1026 ('114 Patent File History) at exhibit pages 1530-31.
[274] Ex. 1026 ('114 Patent File History) at exhibit page 1531.
[275] Ex. 1026 ('114 Patent File History) at exhibit page 1569.
[276] Ex. 1026 ('114 Patent File History) at exhibit page 1609 (10/10/2018 Office Action).

combusting coal, mercury-containing gas containing a halide promoter, injecting a sorbent material, reacting the activated carbon with the sorbent material, separating the mercury/sorbent composition to form a cleaned gas, monitoring the mercury content of the cleaned gas, and controlling a sorbent injection rate.[277] The Examiner relied on the Nelson Publication as a secondary reference to supply one limitation from claim 2, and certain dependent claims:

> [claim 2]: The Nelson reference discloses the halogen or halide promoter comprising Br_2, HBr, Br-, or a combination thereof to promote activated carbon . . . so as to provide an effective carbon sorbent for mercury.
>
> [claim 5]: The Nelson reference discloses optimizing the amount [of bromine] so as to obtain a desired mercury reactivity. It would have been obvious to one having ordinary skill in the art before the invention was made to have modified [Felsvang] to include the promoted sorbent comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material so as to . . . ensure optimum reaction between the halogen and the activated carbon (Nelson paragraph [0054]).
>
> [claim 18]: The Nelson reference discloses the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber (figure 4, objects 71, 64 and 22 and paragraph [0062]). It would have been obvious to one having ordinary skill in the art before the invention was made to have modified the Felsvang et al. reference to include the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separate or a scrubber . . . so the process can be used in a plant which has a "hot-side" ESP and still have effective mercury capture.

[277] Ex. 1026 ('114 Patent File History) at exhibit pages 1609-13 (10/10/2018 Office Action).

> [claim 19]: Nelson Felsvang et al. [sic] reference discloses the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separate or a scrubber (figure, objects 4, 12, 14, 1 and 2).[278]

The Examiner also rejected claim 7 for failing the written-description requirement, stating:

> [Claim 7] contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor . . . , at the time the application was filed, had possession of the claimed invention. *The combusting of the coal forming the halogen or halide promoter in the mercury-containing gas is not within the originally filed specification .”*[279]

The Examiner did not cite Vosteen in this rejection.

191. On December 3, 2018, the applicants sought to overcome the written-description rejection by amending dependent claim 7 as follows: [280]

> 7. (Currently Amended) The method of claim 2, wherein ~~a promoter precursor is on~~ the coal comprises added Br_2, HBr, Br^-, or a combination thereof, ~~wherein the combusting of the coal forms the halogen or halide promoter in the mercury-containing gas~~

As support for this amendment, the applicant cited the following from the as-filed U.S. Patent Application No. 15/978,760 (which ultimately matured into the ’114 Patent) : [281]

[278] Ex. 1026 (’114 Patent File History) at exhibit pages 1609-13 (10/10/2018 Office Action).
[279] Ex. 1026 (’114 Patent File History) at exhibit page 1608 (10/10/2018 Office Action).
[280] Ex. 1026 (’114 Patent File History) at exhibit page 1646.
[281] Ex. 1026 (’114 Patent File History) at exhibit page 1648 (12/3/2018 Resp. to Office Action); Ex. 1026 (’114 Patent File History) at 18-33, 62 (Originally Filed U.S. Patent Application No. 15/978,760).

Claim 7 is presently amended to recite "…wherein ~~a promoter precursor is on~~ the coal comprises added Br_2, HBr, Br^-, or a combination thereof…" Support can be found in the application as-filed at paragraphs [0050] (promoter can be bromide, Br^-), [0064] and [0088] (bromine, bromide, or HBr can be promoter), [0035] (promoter can be introduced upstream of the combustor), paragraphs [0098]-[0107] ("additive" can mean promoter), and FIG. 6 (the additive can be added to the coal).

The applicants also added claim 22 (which ultimately issued as claim 19 in the '114 Patent)

22. (New) The method of claim 2, wherein the coal comprises added halide sorbent enhancement additive.

In an effort to support this new claim, the applicants cited the following from the as-filed U.S. Patent Application No. 15/978,760, and told the Examiner that no new matter was being introduced:

New claim 22 recites "…wherein the coal comprises added halide sorbent enhancement additive." Support can be found at paragraphs [0098]-[0107] ("additive" can mean promoter), paragraph [0010] (the additives can be called "sorbent enhancement additives"), and FIG. 6 (the additive can be added to the coal).

No new matter is added via the amendments herein.

192. On December 26, 2018, the Examiner again rejected the claims for obviousness over Felsvang in view of the Nelson Publication. The Examiner did not re-raise the written-description rejection, and the Examiner did not cite Vosteen. With respect to the Nelson Publication, the Examiner simply copied and repeated

the cited disclosure of the Nelson Publication with respect to the rejection of claims 2, 18, and 19 from the preceding October 10, 2018 office action.[282]

193. As part of the applicants' response on March 20, 2019, the applicants submitted four concurrent declarations totaling forty-five pages from one of the named inventors, John Pavlish, and also with Nicholas Lentz, the applicants' field technical manager, included on one of the four declarations.[283] Additionally as part of the response, the applicants amended the sole independent claim 2 to add features from dependent claims—including dependent claim 7—and introduced new independent claims to the application with limitations similar to those found in amended claim 2.[284] In particular, the applicants amended claim 2 of the ' 760 Application (which ultimately issued as independent claim 1 of the '114 Patent), added application claim 26 (which ultimately issued as independent claim 23), added application claim 27 (which ultimately issued as independent claim 24), and added application claim 28 (which ultimately issued as independent claim 25).[285] The amendment is shown below for application claim 2, and similar limitations were introduced to the remaining independent claims.[286]

[282] Ex. 1026 ('114 Patent File History) at exhibit pages 1692-1712 ('114 Patent File History, 12/26/2018 Office Action).
[283] Ex. 1026 ('114 Patent File History) at exhibit pages 1775-1819
[284] Ex. 1026 ('114 Patent File History) at exhibit pages 1905-11.
[285] Ex. 1026 ('114 Patent File History) at exhibit pages 1905-11.
[286] Ex. 1026 ('114 Patent File History) at exhibit pages 1905.

2. (Currently Amended) A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br˙, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br˙, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br˙, or a combination thereof, or a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber ~~such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent~~;

~~reacting~~contacting mercury in the mercury-containing gas with the ~~promoted~~ sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas, and

controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.

The applicants also amended claim 7 to recite:[287]

7. (Currently Amended) The method of claim 2, wherein the coal comprises added Br_2, HBr, Br˙, or a combination thereof, added to the coal upstream of the combustion chamber.

In support of the amendment of the claims regarding the specific type of bromine chemical and its location of addition, applicants identified the following from the '760 Application:[288]

[287] Ex. 1026 ('114 Patent File History) at exhibit pages 1905-11.

[288] Ex. 1026 ('114 Patent File History) at exhibit page 1824 (3/20/2019 Resp. to Office Action); *see* Ex. 1026 ('114 Patent File History) at 38-49, 62.

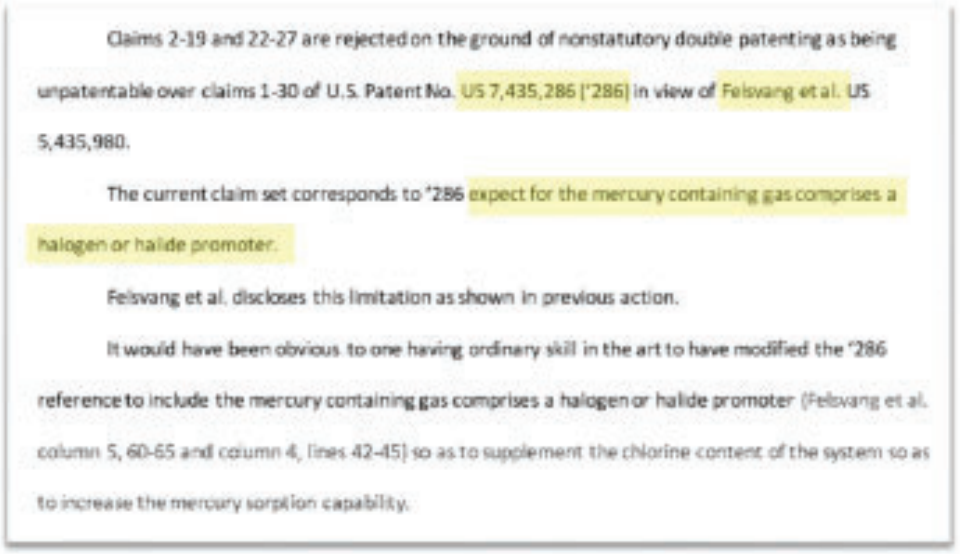
> Independent claim 2 is presently amended to recite "…the coal comprises added Br_2, HBr, Br', or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br', or a combination thereof, or a combination thereof…." Claim 7 is amended to recite "…wherein the coal comprises added Br_2, HBr, Br', or a combination thereof, added to the coal upstream of the combustion chamber." Support can be found in the application as filed at paragraphs [0123]-[0125], [0138], [0164], and figure 6. At paragraph [0138] the application states that the invention includes a sorbent and a combination of additives to remove pollutants from the gas stream. At paragraph [0164], "[t]he additive can be injected where desired (e.g., before, after, or within the boiler)." Paragraphs [0124]-[0125] state that the "additives" can include those listed in Example 1E, which include HBr and Br_2. HBr includes Br'. Paragraphs [0088] and [0155] state that the reactive carbon form "can be generated by the addition or bromine, hydrogen bromide, or combinations of bromine and other elements as described herein." Compounds including bromine and other elements are bromide compounds that include Br'. Paragraph [0144] states that "…a bromine compound…" can be used to form the promoted sorbent; a compound including bromine is a bromide compound that includes Br'.

194. On April 19, 2019, the Examiner agreed to allow claims 2-19 and 22-28 because "as shown within the declarations, in flight promotion with HBR [*sic,* HBr] or Br promoters is more effective for mercury removal than treating the sorbent with HBr, Br or Br_2 outside the mercury-containing gas."[289]

195. With this indication of allowance the Examiner also maintained a nonstatutory double patenting rejection of all of the pending claims first made in the October 10, 2018 office action—before the introduction of independent claims 23-25 and before substantively amending independent claim 1, as issued in the '114 Patent, that each require some bromine-containing species added to either the coal or the combustion chamber. In making this double patenting rejection, the Examiner focused on the "mercury containing gas comprises a halogen or halide promoter,"

[289] Ex. 1026 ('114 Patent File History) at exhibit page 1926.

but not on the multitude of limitations added during prosecution of the '114 Patent:[290]



Claims 2-19 and 22-27 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-30 of U.S. Patent No. US 7,435,286 ['286] in view of Felsvang et al. US 5,435,980.

The current claim set corresponds to '286 expect for the mercury containing gas comprises a halogen or halide promoter.

Felsvang et al. discloses this limitation as shown in previous action.

It would have been obvious to one having ordinary skill in the art to have modified the '286 reference to include the mercury containing gas comprises a halogen or halide promoter (Felsvang et al. column 5, 60-65 and column 4, lines 42-45) so as to supplement the chlorine content of the system so as to increase the mercury sorption capability.

After the applicants filed a terminal disclaimer to address the double patenting rejection, the Examiner ultimately allowed the claims on April 23, 2019.[291]

3. Filing of the '225 Patent

196. The continuation application that ultimately issued as the '225 Patent was filed on May 14, 2015 as the '558 Application. The application did not include Figure 2 of the provisional application. There was only one claim in the application as filed, and that claim made no reference to pyrolysis char:

[290] Ex. 1026 ('114 Patent File History) at exhibit page 1921.
[291] Ex. 1026 ('114 Patent File History) at exhibit pages 1961-67 (5/8/2019 Notice of Allowance).

CLAIMS

WE CLAIM:

1. A promoted carbon sorbent comprising a base activated carbon that has reacted with a promoter selected from the group consisting of halides, halogens, and combinations thereof, such that the reaction product is effective for the removal of mercury from a gas stream.

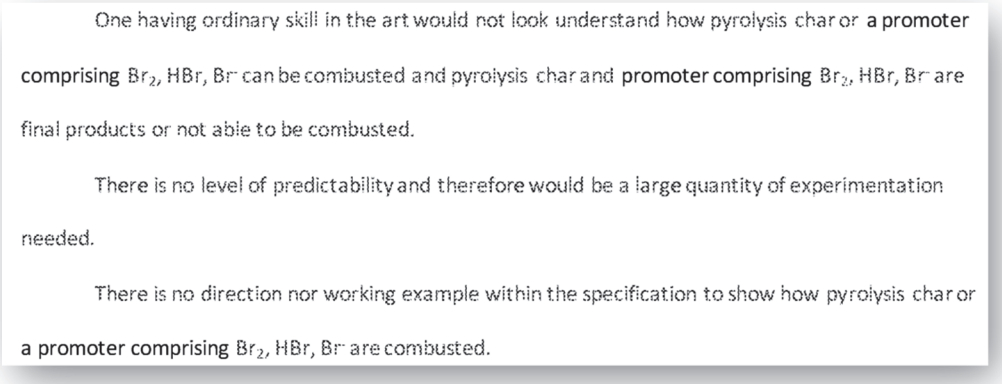
197. On the next day, however, the applicant filed a preliminary amendment with 21 claims.[292] The claims related generally to the promotion of sorbent material for capturing mercury. The promoter was not limited to bromine compounds.

4. ’225 Subsequent Prosecution History

198. On July 6, 2017, the examiner issued a non-final rejection of all claims. The claims were rejected under 35 U.S.C. 112 as failing to comply with the written description and enablement requirement for failing to include an subject matter in the specification disclosing the combustion of coal with a promoter from halides or halogens, and no working examples addressing those claim elements. In response the applicant argued that Figure 2 of the provisional provided support for the addition of the promoter to the coal before entering the furnace.[293] The examiner responded to state that it was not clear that the “additive” of Figure 2 of the provisional was the same as the claimed promoter.[294] On April 2, 2018, the applicant

[292] ’558 File History at 2015-05-15 Preliminary amendment.
[293] ’558 File History at 2017-10-06 Amendment and Remarks.
[294] ’558 File History at 2017-10-06 Final Rejection.

filed a Request for Continued Examination with new claims, and note that he had canceled "all claims explicitly reciting application of the promoter or promoter precursor to the coal prior to combustion."[295] On June 13, 2018, following another rejection, the applicant submitted newly amended claims that included the element of "combusting a mixture comprising coal, pyrolysis char and a promoter."[296] The applicant cited to support in the specification for using pyrolysis char as the sorbent to provide written description for using pyrolysis char in the combustion zone.[297] On July 2, 2018 the examiner rejected the claims under section 112 as lacking enablement:[298]



One having ordinary skill in the art would not look understand how pyrolysis char or a promoter comprising Br_2, HBr, Br^- can be combusted and pyrolysis char and promoter comprising Br_2, HBr, Br^- are final products or not able to be combusted.

There is no level of predictability and therefore would be a large quantity of experimentation needed.

There is no direction nor working example within the specification to show how pyrolysis char or a promoter comprising Br_2, HBr, Br^- are combusted.

[295] '558 File History at 2018-04-02 Amendment and Remarks.
[296] '558 File History at 2018-06-13 Amendment and Remarks.
[297] '558 File History at 2018-06-13 Amendment and Remarks, pages 8-9.
[298] '558 File History at 2018-06-13 Non-Final Rejection, pages 2-3.

199. Through the interview process, it appears that the applicant was able to convince the examiner that there was support for the sorbent being within the combustion process.[299]

200. The claims were later rejected over Nelson in light of Felsvang, by arguing that Nelson did not disclose in-flight promotion, and by relying on the inventor's declarations discussed below.[300]

201. The claims were allowed in their final form on December 13, 2019.

5. Filing of the '517 Patent

202. The continuation application that ultimately issued as the '517 Patent was filed on June 4, 2018 as the '091 Application. Similar to the '343 Application, when ME2C filed the '091 Application on June 4, 2018, ME2C copied and pasted the contents of the Provisional, which had not been explicitly included in any of the earlier applications in the priority chain filed before the '970 Application. I note that ME2C renumbered Figure 2 of the Provisional as Figure 11 of the '091 Application.

203. As originally filed, the '091 Application included 20 claims, of which one was an independent claim, and 11 drawings (Figures 1-11).

204. Independent claim 1, as originally filed, did not include any limitations directed to coal having added bromine-containing species or restricting

[299] '558 File History at 2018-07-02 Interview Summary.
[300] '558 File History at 2019-07-10 Amendment and Remarks.

the location at which the bromine-containing species is added to the coal. Through subsequent amendments during substantive examination, ME2C introduced limitations into the independent claims relating to adding specific types of bromine-containing species to the coal itself (before the coal enters the combustion chamber) that were ultimately included in each of the independent claims of the '517 Patent.

6. '517 Subsequent Prosecution History

205. On July 27, 2018, the Examiner issued a non-final rejection of all the pending claims of the '091 Application.[301] Independent claim 1 and dependent claims 4-14 and 16-19 were rejected as being anticipated by U.S. Patent App. Pub. No. 2004/0003716 to Nelson (the "Nelson Publication").[302] The remaining dependent claims were rejected as being obvious over combinations of the Nelson Publication in view of various secondary references, including U.S. Patent App. Pub. No. 2007/0168213 to Comrie and U.S. Patent No. 6,878,358 to Vosteen.[303] The Examiner also rejected the claims on the ground of non-statutory obviousness type double patenting.[304]

206. In ME2C's response filed on August 14, 2018, ME2C argued against the anticipation and obviousness rejections without making any

[301] '517 Patent File History at July 27, 2018 Non-Final Rejection
[302] '517 Patent File History at July 27, 2018 Non-Final Rejection, pages 2-4
[303] '517 Patent File History at July 27, 2018 Non-Final Rejection, pages 4-7
[304] '517 Patent File History at July 27, 2018 Non-Final Rejection, pages 7-10

amendments to the claims.[305] In an attempt to distinguish the claims from the Nelson Publication, ME2C argued that the Nelson Publication does not disclose "the claimed feature of in-flight promotion of activated carbon sorbent, wherein at the time of promotion the sorbent is dispersed in a steam [sic] of transport air or other gas that conveys the sorbent particles from one location to another in a mercury-removal system."[306] ME2C also argued that the Comrie reference is not prior art to the pending claims.[307]

207. On November 2, 2018, the Examiner issued another non-final rejection in which the anticipation rejection based on the Nelson Publication was maintained.[308] The Examiner also rejected independent claim 1 and certain dependent claims as obvious over a combination of U.S. Patent No. 5,435,980 to Felsvang (as the primary reference) and the Nelson Publication (as a secondary reference).[309] The Examiner found that Felsvang disclosed almost all the limitations from independent claim 1, including injecting a sorbent into the mercury-containing gas, collecting mercury in the mercury-containing gas on the sorbent to produce a cleaned gas, wherein the sorbent is a promoted activated carbon that is promoted in-flight with at least one promoter wherein the mercury-

[305] '517 Patent File History at August 14, 2018 Response
[306] '517 Patent File History at August 14, 2018 Response, pages 5-6
[307] '517 Patent File History at August 14, 2018 Response, page 6
[308] '517 Patent File History at November 2, 2018 Non-Final Rejection, pages 3-5
[309] '517 Patent File History at November 2, 2018 Non-Final Rejection, pages 9-12

containing gas is a coal-combustion gas.[310] The Examiner relied on the Nelson Publication to disclose the limitation directed to the promoter being Br2, HBr, Br- or a combination thereof.[311] The Examiner also maintained the non-statutory obviousness double patenting rejections and issued several new double patenting rejections over a number of issued patents and pending applications in the '517 Patent's priority chain.[312]

208. In a response filed on December 3, 2018, ME2C made several amendments to the pending claims, including amendments to independent claim 1. ME2C amended independent claim 1 to add the following limitation: "combusting coal that comprises an additive comprising Br2, HBr, Br-, or a combination thereof, to form the mercury-containing gas, wherein the combusting of the coal is performed at a coal combustion facility site."[313] In support of this amendment regarding the specific type of bromine species added to the coal, ME2C identified the following passages of the published '091 Application:[314]

[310] '517 Patent File History at November 2, 2018 Non-Final Rejection, page 9
[311] *Id.*
[312] '517 Patent File History at November 2, 2018 Non-Final Rejection, pages 12-23
[313] '517 Patent File History at December 3, 2018 Response, page 2
[314] '517 Patent File History at December 3, 2018 Response, page 5

Independent claim 1 is amended to recite "…combusting coal that comprises an additive comprising Br_2, HBr, Br^-, or a combination thereof, to form the mercury-containing gas, wherein the combusting of the coal is performed at a coal combustion facility site…." Support can be found in the present published application at paragraphs [0042] (promoter can be bromide, Br^-), [0054] and [0072] (bromine, bromide, or HBr can be promoter), paragraphs [0077]-[0086] ("additive" can mean promoter), and FIG. 11 (the additive can be added to the coal).

209. With respect to the anticipation rejection, ME2C argued that the Nelson Publication does not disclose the newly introduced feature of "combusting coal that includes an additive that includes Br2, HBr, Br-, or a combination thereof, to form the mercury-containing gas, wherein the combusting of the coal is performed at a coal combustion facility site."315 With respect to the obviousness rejections, ME2C argued that there would have been no motivation for a POSITA to use the bromide additives from the Nelson Publication in Felsvang's process and that "in-flight promotion with bromide promoters is more effective for mercury removal than treating the sorbent with bromide or bromine additives outside the mercury-containing gas."316

210. On January 11, 2019, the Examiner issued a final rejection, removing the anticipation rejection based on the Nelson Publication and maintaining the obviousness rejections based on Felsvang and the Nelson Publication.317

315 '517 Patent File History at December 3, 2018 Response, page 8
316 '517 Patent File History at December 3, 2018 Response, pages 8-30
317 '517 Patent File History at January 11, 2019 Final Rejection

Specifically, the Examiner maintained that it would have been obvious to modify Felsvang with the Nelson Publication to "either replace the Cl with or include in addition to the Cl, Br2, HBr, Br- or a combination thereof … so as to provide an effective carbon sorbent for mercury."[318]

211. ME2C filed a response with a request for continued examination on July 10, 2019.[319] In the response, ME2C amended independent claim 1 as well as a number of the dependent claims. The amendments to independent claim 1 are shown below:[320]

1. (Currently Amended) A method for reducing mercury in a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, the coal[[that]] compris[[es]]ing an additive comprising Br_2, HBr, [[Br^-]]a bromide compound, or a combination thereof, to form the mercury-containing gas~~, wherein the combusting of the coal is performed at a coal combustion facility site~~;

collecting mercury in the mercury-containing gas [[on]]with a sorbent comprising~~to produce a cleaned gas, wherein the sorbent comprises a promoted~~ activated carbon~~that is promoted in flight in a gas stream at the coal combustion facility site comprising contacting activated carbon dispersed in the gas stream with at least one promoter comprising HBr, Br^-, or a combination thereof~~.

212. ME2C also added twenty-two new claims, including two new independent claims. The newly introduced independent claims 41 and 42 are shown below:[321]

[318] '517 Patent File History at January 11, 2019 Final Rejection, page 3
[319] '517 Patent File History at July 10, 2019 Response
[320] '517 Patent File History at July 10, 2019 Response, page 2
[321] '517 Patent File History at July 10, 2019 Response, page 7

41. (New) A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, wherein

the coal comprises added Br_2, HBr, bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, bromide compound, or a combination thereof, or

a combination thereof;

collecting mercury in the mercury-containing gas with a sorbent comprising activated carbon.

42. (New) A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, bromide compound, or a combination thereof, or

a combination thereof;

collecting mercury in the mercury-containing gas with a sorbent comprising activated carbon;

separating the sorbent contacted with the mercury from the mercury-containing gas;

measuring the mercury content of the mercury-containing gas; and

modifying, in response to the measured mercury content of the mercury-containing gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

an amount of the Br_2, HBr, bromide compound, or a combination thereof, added to the coal or the combustion chamber, or

a combination thereof.

213. Additionally as part of ME2C's response, ME2C submitted four concurrent declarations totaling forty-five pages from one of the named inventors,

John Pavlish, with Nicholas Lentz, ME2C's field technical manager, included on one of the four declarations.322

214. On August 23, 2019, the Examiner issued a non-final rejection, rejecting claim 1323 under Section 112(b) for being incomplete for omitting essential steps and maintaining the double patenting rejections.324 In response to the non-final rejection, ME2C amended independent claim 1 to further specify that the sorbent is "added to the mercury-containing gas."325 ME2C also filed a terminal disclaimer to address the double patenting rejections.326 The Examiner ultimately allowed the claims on September 18, 2019.327

215. After having paid the issue fee on September 27, 2019, ME2C filed a certification and request for consideration of an information disclosure statement under the QPIDS pilot program.328 The inf ormation disclosure statement submitted by ME2C cited, for the first time during prosecution of the '517 Patent, various presentations and publications from 2003 that were authored or presented by the first named inventor, Edwin Olson.329 The information disclosure

322 '517 Patent File History at July 10, 2019 Response
323 The August 23, 2019 Non-Final Rejection states that claim 11 is rejected under Section 112(b). However, as noted in ME2C's August 28, 2019 Response, it is believed this was an error and the Examiner intended to reject independent claim 1 instead of dependent claim 11.
324 '517 Patent File History at August 23, 2019 Non-Final Rejection, pages 2-10
325 '517 Patent File History at August 28, 2019 Response, page 2
326 '517 Patent File History at August 28, 2019 Terminal Disclaimer Filing
327 '517 Patent File History at September 18, 2019 Notice of Allowance
328 '517 Patent File History at November 11, 2019 Quick Path Information Disclosure Statement
329 '517 Patent File History at November 11, 2019 Information Disclosure Statement

statement also cited several documents filed in the pending federal district court lawsuit.330

216. The Examiner issued a Notice of Allowance on November 22, 2019 allowing the claims that ultimately issued as the ’517 Patent.[331]

7. Filing of the ’430 Patent

217. The continuation application that ultimately issued as the ’430 Patent was filed on May 8, 2018 as the ’343 Application. When ME2C filed the ’343 Application on May 8, 2018, ME2C copied and pasted the contents of the Provisional, which had not been explicitly included in any of the earlier applications in the priority chain filed before the ’970 Application. I note that ME2C renumbered Figure 2 of the Provisional as Figure 11 of the ’343 Application.

218. As originally filed, the ’343 Application included 20 claims, of which two were independent claims, and 11 drawings (Figures 1-11).[332] As filed, independent claims 1 and 20 of the ’343 Application are reproduced below:

[330] *Id.*
[331] ’517 Patent File History at November 22, 2019 Notice of Allowance
[332] ’430 Patent File History at May 8, 2018 application filing

1. A method for separating mercury from a mercury-containing gas, the method comprising:

combusting a mixture of coal and an additive, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas;

promoting at least a portion of the sorbent material by chemically reacting the sorbent material with the additive in the mercury-containing gas, to form a promoted sorbent material;

chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent; and

separating the mercury-sorbent from the mercury-containing gas.

20. A method for separating mercury from a mercury-containing gas, the method comprising:

combusting coal mixed with an additive, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas;

injecting a sorbent material comprising activated carbon into the mercury-containing gas;

promoting at least a portion of the sorbent material by chemically reacting the sorbent material with the additive in the mercury-containing gas, to form a promoted sorbent material;

chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent; and

separating the mercury-sorbent from the mercury-containing gas;

wherein the coal and promoter are mixed at a location upstream of a combustion furnace where combustion occurs.

219. Independent claims 1 and 20, as originally filed, included a limitation directed to combusting coal mixed with an additive. The independent claims, however, did not require any particular type of bromine-containing species added to the coal and generally referred to the "additive" as "halides, halogens, salts thereof, and combinations thereof." Through subsequent amendments in a preliminary

amendment and during substantive examination, ME2C introduced limitations into the independent claims relating to adding specific types of bromine-containing species to the coal itself that were ultimately included in each of the independent claims of the ’430 Patent.

8. ’430 Subsequent Prosecution History

220. Shortly after the ’343 Application was filed, on May 15, 2018, a preliminary amendment was submitted that canceled independent claim 20 and several dependent claims and added new claims 21-25.[333] In the preliminary amendment, ME2C also amended the claims to further specify that the additive “has been added to the coal” and that the additive includes “a bromide compound” (as recited in claim 1) and “Ca, Na, or a combination thereof” (as recited in claim 10).[334] Amended independent claim 1 and dependent claim 10 are reproduced below:

[333] ’430 Patent File History at May 15, 2018 Preliminary Amendment
[334] ’430 Patent File History at May 15, 2018 Preliminary Amendment, pages 2-3

1. (Currently Amended) A method for separating mercury from a mercury-containing gas, the method comprising:

combusting a mixture of coal and an additive that has been added to the coal, the additive comprising a bromide compound, to form the mercury-containing gas~~, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof~~;

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas;

promoting at least a portion of the sorbent material by chemically reacting the sorbent material with ~~the additive~~Br_2, HBr, Br^-, or a combination thereof, in-flight ~~the mercury-containing gas~~, to form a promoted sorbent material;

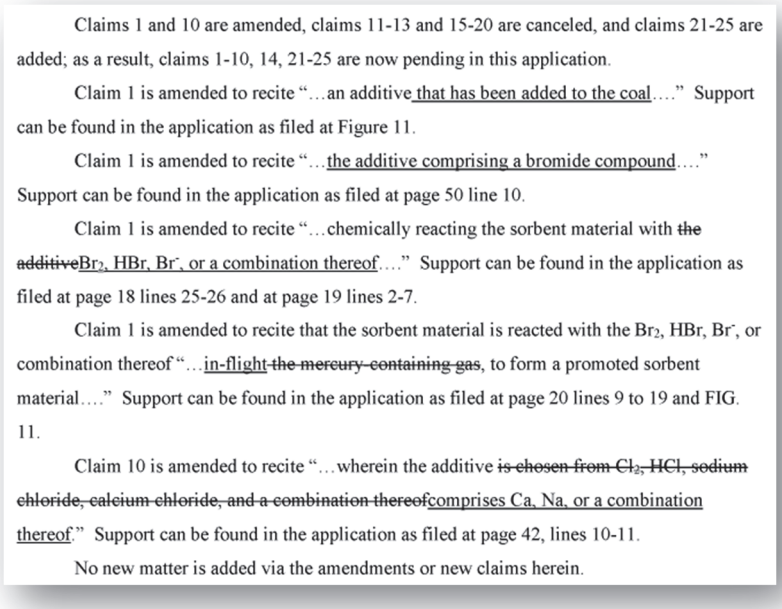
chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent; and

separating the mercury-sorbent from the mercury-containing gas.

10. (Currently Amended) The method of claim 1, wherein the additive ~~is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof~~comprises Ca, Na, or a combination thereof.

221. In an effort to support these amendments, ME2C cited the following passages from the as-filed '343 Application, and told the Examiner that no new matter was being introduced:[335]

[335] '430 Patent File History at May 15, 2018 Preliminary Amendment, page 6



Claims 1 and 10 are amended, claims 11-13 and 15-20 are canceled, and claims 21-25 are added; as a result, claims 1-10, 14, 21-25 are now pending in this application.

Claim 1 is amended to recite "…an additive that has been added to the coal…." Support can be found in the application as filed at Figure 11.

Claim 1 is amended to recite "…the additive comprising a bromide compound…." Support can be found in the application as filed at page 50 line 10.

Claim 1 is amended to recite "…chemically reacting the sorbent material with ~~the additive~~Br_2, HBr, Br^-, or a combination thereof…." Support can be found in the application as filed at page 18 lines 25-26 and at page 19 lines 2-7.

Claim 1 is amended to recite that the sorbent material is reacted with the Br_2, HBr, Br^-, or combination thereof "…in-flight ~~the mercury-containing gas~~, to form a promoted sorbent material…." Support can be found in the application as filed at page 20 lines 9 to 19 and FIG. 11.

Claim 10 is amended to recite "…wherein the additive ~~is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof~~comprises Ca, Na, or a combination thereof." Support can be found in the application as filed at page 42, lines 10-11.

No new matter is added via the amendments or new claims herein.

222. On July 27, 2018, the Examiner issued a non-final rejection of all the pending claims of the '343 Application, *i.e.*, claims 1-10, 14, and 21-25.[336] Independent claim 1 and dependent claims 2, 5-8, 14, and 21-24 were rejected as being obvious over a combination of U.S. Patent App. Pub. No. 2004/0003716 by Nelson (the "Nelson Publication") in view of U.S. Patent App. Pub. No. 2007/0168213 by Comrie ("Comrie").[337] With regard to Nelson, the Examiner relied on the reference for purposes of disclosing all the features of independent claim 1, except for "combusting the coal in the presence of an additive that has been added to the coal, the additive comprising a bromide compound."[338] The Examiner relied on Comrie for disclosing that limitation.

[336] '430 Patent File History at July 27, 2018 Non-Final Rejection
[337] '430 Patent File History at July 27, 2018 Non-Final Rejection, pages 3-6
[338] '430 Patent File History at July 27, 2018 Non-Final Rejection, page 3

223. The Examiner rejected the remaining dependent claims over the Nelson Publication and Comrie in view of several other references. Specifically, claim 4 was rejected as being obvious over a combination of the Nelson Publication, Comrie, and U.S. Patent No. 6,848,374 to Srinivasachar.[339] Claim 10 was rejected as being obvious over a combination of the Nelson Publication, Comrie, and U.S. Patent No. 6,136,749 to Gadkaree.[340] Claim 25 was rejected as being obvious over a combination of the Nelson Publication, Comrie, and U.S. Patent No. 6,878,358 to Vosteen.[341] The Examiner also rejected claims 1-2, 5-10, and 21-25 on the ground of non-statutory obviousness double patenting over U.S. Patent No. 7,435,286 (the "'286 Patent") in view of Comrie.[342]

224. On August 14, 2018, ME2C filed a response to the non-final rejection.[343] ME2C did not make any amendments to the pending claims. Instead, ME2C argued that Comrie is not prior art to the pending claims, and independent claim 1 is patentable because no cited reference that is applicable as prior art "describes or suggests combusting coal in the presence of an additive that includes a bromide compound."[344]

[339] '430 Patent File History at July 27, 2018 Non-Final Rejection, page 6
[340] '430 Patent File History at July 27, 2018 Non-Final Rejection, page 7
[341] '430 Patent File History at July 27, 2018 Non-Final Rejection, pages 7-8
[342] '430 Patent File History at July 27, 2018 Non-Final Rejection, pages 8-10
[343] '430 Patent File History at August 14, 2018 Response
[344] '430 Patent File History at August 14, 2018 Response, pages 5-6

225. On October 29, 2018, the Examiner issued another non-final rejection, rejecting independent claim 1 and certain dependent claims as obvious over a combination of U.S. Patent No. 5,435,980 to Felsvang (as the primary reference) and the Nelson Publication (as a secondary reference).[345] The Examiner found that Felsvang disclosed almost all the limitations from independent claim 1, including combusting a mixture of coal and an additive that has been added to the coal to form the mercury-containing gas, adding a particulate sorbent material comprising activated carbon into the mercury-containing gas, chemically reacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent, and separating the mercury-sorbent from the mercury-containing gas.[346] The Examiner relied on the Nelson Publication as a secondary reference to supply one limitation from independent claim 1, specifically, that the additive comprises a bromide compound.[347] The Examiner also maintained the non-statutory obviousness double patenting rejection over the '286 Patent and issued several new double patenting rejections over a number of issued patents and pending applications in the '430 Patent's priority chain.[348]

226. In a response filed on December 3, 2018, ME2C made several amendments to the pending claims, including amendments to independent claim 1

[345] '430 Patent File History at October 29, 2018 Non-Final Rejection, pages 3-7
[346] '430 Patent File History at October 29, 2018 Non-Final Rejection, page 4
[347] *Id.*
[348] '430 Patent File History at October 29, 2018 Non-Final Rejection, pages 9-17

and the addition of a new claim.[349] ME2C added new claim 26 to further specify that the "additive comprises Br_2, HBr, Br^-, or a combination thereof."[350] In support of this new claim regarding the specific type of bromine additive, ME2C identified the following passages of the published '343 Application:[351]

> New claim 26 is added, reciting "…wherein the additive comprises Br_2, HBr, Br^-, or a combination thereof." Support can be found in the present published application at paragraphs [0042] (promoter can be bromide, Br^-), [0054] and [0072] (bromine, bromide, or HBr can be promoter), paragraphs [0077]-[0086] ("additive" can mean promoter), and FIG. 11 (the additive can be added to the coal). Claim 26 is dependent on independent claim 1 and, as such, incorporates all the features of claim 1. Accordingly, new dependent claim 26 is patentable for at least the reasons given herein for patentability of independent claim 1.
>
> No new matter is added via the new claims herein.

227. In its response, ME2C attempted to distinguish the amended claims from Felsvang and the Nelson Publication by arguing that there would have been no motivation for a POSITA to use the bromide additives from the Nelson Publication in Felsvang's process and that "in-flight promotion with bromide promoters is more effective for mercury removal than treating the sorbent with bromide or bromine additives outside the mercury-containing gas."[352]

[349] '430 Patent File History at December 3, 2018 Response
[350] '430 Patent File History at December 3, 2018 Response, page 4
[351] '430 Patent File History at December 3, 2018 Response, page 5
[352] '430 Patent File History at December 3, 2018 Response, pages 7-28

228. On January 14, 2019, the Examiner again rejected independent claim 1 and certain dependent claims for obviousness over Felsvang in view of the Nelson Publication.[353] The Examiner maintained that the Nelson Publication discloses "the additive comprising a bromide compound, Br_2, HBr and Br^- and promoters including HBr, Br^- or a combination thereof" and that it would have been obvious to modify Felsvang to "either replace the Cl promoter/additive with or include in addition to the Cl promoter/additive, with an additive comprising a bromide compound, Br_2, HBr and Br^- and promoters including HBr, Br- or a combination thereof … so as to provide an effective carbon sorbent for mercury."[354]

229. ME2C filed a response with a request for continued examination on July 10, 2019.[355] In the response, ME2C canceled all previously pending claims and added twenty-nine new claims, of which three were independent claims. [356] Each of the three new independent claims introduced the specific type of bromine chemical recited in the previous dependent claim 26 and restricted the location at which the bromine chemical is added, specifically, to either the coal itself or to the combustion chamber.[357] Additionally as part of ME2C's response, ME2C submitted four concurrent declarations totaling forty-five pages from one of the named

[353] '430 Patent File History at January 14, 2019 Final Rejection, pages 2-6
[354] '430 Patent File History at January 14, 2019 Final Rejection, pages 3-4
[355] '430 Patent File History at July 10, 2019 Response
[356] '430 Patent File History at July 10, 2019 Response, pages 2-6
[357] *Id.*

inventors, John Pavlish, with Nicholas Lentz, ME2C's field technical manager, included on one of the four declarations.[358]

230. On August 21, 2019, the Examiner agreed to allow the pending claims.[359] With this indication of allowance, the Examiner also maintained the non-statutory double patenting rejections made in the October 29, 2018 office action.[360] After ME2C filed a terminal disclaimer to address the double patenting rejections, the Examiner issued a Notice of Allowance on September 17, 2019.[361]

231. After having paid the issue fee on September 27, 2019, ME2C filed a certification and request for consideration of an information disclosure statement under the QPIDS pilot program.[362] The information disclosure statement submitted by ME2C cited, for the first time during prosecution of the '430 Patent, various presentations and publications from 2003 that were authored or presented by the first named inventor, Edwin Olson.[363] The information disclosure statement also cited several documents filed in the pending federal district court lawsuit.[364]

232. In response to ME2C's request for consideration of the information disclosure statement, the Examiner issued a non-final rejection,

[358] '430 Patent File History at July 10, 2019 Response
[359] '430 Patent File History at August 21, 2019 Non-Final Rejection, page 11
[360] '430 Patent File History at August 21, 2019 Non-Final Rejection, pages 2-11
[361] '430 Patent File History at September 17, 2019 Notice of Allowance
[362] '430 Patent File History at November 11, 2019 Quick Path Information Disclosure Statement
[363] '430 Patent File History at November 11, 2019 Information Disclosure Statement
[364] *Id.*

rejecting the claims for failing to comply with the written description requirement.[365] In particular, the Examiner stated that the originally filed disclosure, including the disclosure of the Provisional, does not provide adequate support for the claim limitation relating to "the coal comprising added Br_2, HBr, a bromide compound or a combination thereof."[366] The Examiner also issued new provisional double patenting rejections.[367]

233. ME2C filed a response to the non-final rejection on April 2, 2020. To overcome the written description rejection, ME2C amended the independent claims to replace "added" with the term "additive:"[368]

> Merely to expedite prosecution, independent claim 27 is presently amended to recite "…the coal comprises ~~added~~an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber, or the combustion chamber comprises ~~added~~an additive comprising Br_2, HBr, a bromide compound, or a combination thereof…." Independent claims 54-55, and dependent claims 28-31, are correspondingly amended.

234. In an attempt to provide support for these amendments, ME2C stated that "[t]he amendments align the additive feature in the present claims with claim 1 of the related matter U.S. application no. 15/997,091 now issued as U.S. patent no.

[365] '430 Patent File History at December 2, 2019 Non-Final Rejection, pages 2-3
[366] *Id.*
[367] *Id.* at pages 3-6
[368] '430 Patent File History at April 2, 2020 Response, pages 2-7, 9

10,596,517."[369] After ME2C filed a terminal disclaimer to address the additional double patenting rejections, the Examiner ultimately allowed the claims on April 13, 2020.[370]

XIV. PRIORITY DATE ANALYSIS

A. PRIORITY ANALYSIS FOR THE '147 PATENT

235. I have been asked to review the '147 Patent, and its earlier filed parent applications, from the perspective of a POSITA, and to look for support for Claims 17-20 of the '147 Patent. I understand from the family tree[371] that the '147 Patent was filed through a series of patent applications back to the Provisional, filed on August 30, 2004. I have been informed that, in order for a patent claim to be entitled to the priority date of an earlier-filed application, each and every element of that claim must be fully supported by the disclosure of both: (a) the earlier-field application; and (b) all intervening applications in the chain.

236. The '147 Patent contains a single independent claim (claim 1) directed to "[a] method for separating mercury from a mercury containing gas."[372] Claim 1 requires "promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter."[373] Claim 17 depends from claim 1 and further requires

[369] '430 Patent File History at April 2, 2020 Response, page 10
[370] '430 Patent File History at April 13, 2020 Notice of Allowance
[371] Ex. 1017 (Family Tree).
[372] Ex. 1001 ('147 Patent) at claim 1.
[373] Ex. 1001 ('147 Patent) at claim 1.

"injecting the particulate sorbent material at a sorbent material injection rate and injecting ***separately*** the bromine containing promoter into a gas stream whereby ***in-flight reaction*** produces the promoted brominated sorbent."[374] Claim 18 depends from claim 17 and specifies that "the gas stream [of claim 17] is a mercury containing gas."[375] Claim 19 depends from Claim 18 and further specifies that "the gas stream is a transport gas."[376] Claim 20 depends from Claim 17 and it further specifies that "the promoter injection rate and the sorbent injection rate into the gas are determined at least in part on the monitored mercury content of the cleaned gas."[377]

237. 256. Through its their dependency on claims 1 and 17, the subject matter of Cclaims 18 and 20 requires: "injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into [a mercury-containing gas] whereby in-flight reaction produces the promoted brominated sorbent."

238. Through its dependency on claims 1, 17, and 18, the subject matter of claim 19 requires: "injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into [a

374 Ex. 1001 ('147 Patent) at claim 17 (emphasis added).
375 Ex. 1001 ('147 Patent) at claim 18.
376 Ex. 1001 ('147 Patent) at claim 19.
377 Ex. 1001 ('147 Patent) at claim 20.

mercury containing gas that is a transport gas] whereby in-flight reaction produces the promoted brominated sorbent."

239. As discussed above, the '147 Patent was filed on April 6, 2009 and claims priority through a chain of several earlier applications: U.S. Patent Application No. 12/201,595 filed on August 29, 2008 (the "'595 Application"); U.S. Patent Application No. 11/209,163 (the "'163 Application"), filed on August 22, 2005 and which issued as U.S. Pat. No. 7,435,286 (the "'286 Patent"); and ultimately to the Provisional, filed August 30, 2004.

240. I have reviewed the specifications, figures, claims, and prosecution histories of the Provisional, the '163 Application, the '595 Application, and the '147 Patent. During my review, I specifically looked for any disclosure of: (a) injecting the sorbent material separately from the bromine containing promoter into a mercury-containing gas stream; such that (b) in-flight reaction in the mercury-containing gas produces the promoted brominated sorbent, as required by claim 18 of the '147 Patent. In addition, I also looked for any disclosure of the above in which the mercury-containing gas (as per claim 18) is also a transport gas, as required by claim 19 of the '147 Patent.

241. I determined that none of the other applications between the Provisional and the filing of the '219 Application—the application that led to the '147 Patent—include any disclosure of Claims 17, 18, 19, and 20. The only disclosure of Claims

17, 18, 19, and 20 in the '147 Patent, or any of the applications from which it claims priority, is found in the language of the claims themselves, which were first introduced in the April 6, 2009 preliminary amendment.

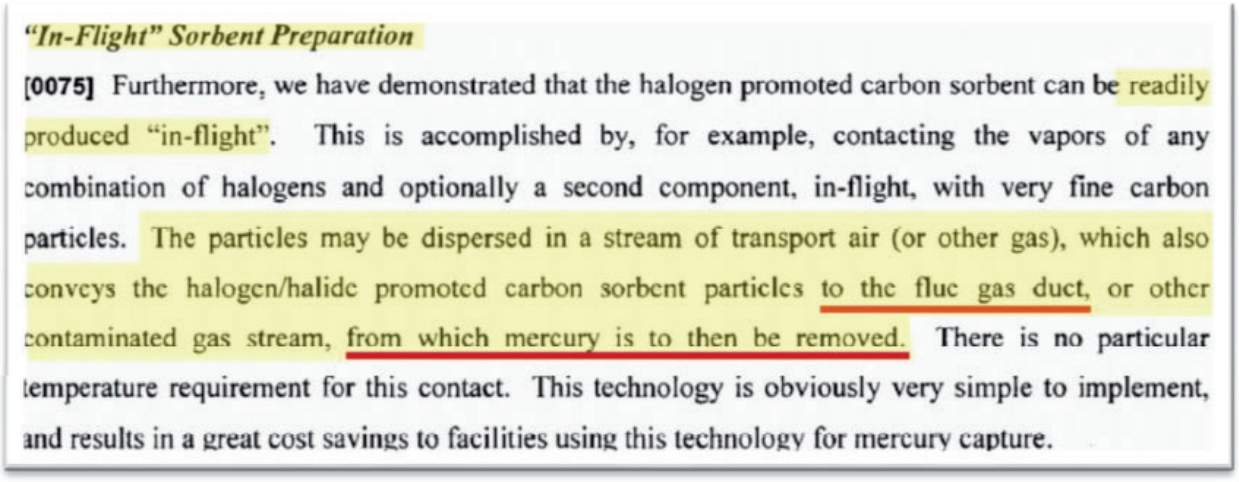
1. No Disclosure of Claims 17, 18, 19 and 20 in the '163 or '595 Applications

242. The '163 Application and the '595 Application, which are parents to the '147 Patent, do not disclose the subject matter of Claims 17-20. The '163 and '595 Applications repeatedly describe treating a base activated-carbon sorbent with a bromine promoter ***prior to*** injecting the prepared promoted sorbent into a mercury-containing flue gas, such that: (a) the sorbent material and bromine containing promoter are ***not*** injected "separately" into the mercury-containing gas (they are injected together); and (b) an in-flight reaction between sorbent and promoter occurs ***prior to*** injection into the mercury-containing gas, and not in the "gas stream [that] is a mercury-containing gas."

243. The '163 and '595 Applications repeatedly describe "in-flight" promotion as "contacting the vapors of any combination of halogens and optionally a second component, in-flight with very fine carbon particles."[378] But the only examples provided in those documents of such treatment of activated carbon with a bromine promoter occurs ***before*** introduction into the mercury-containing flue gas.

[378] Ex. 1021 ('163 Application File History) at exhibit pages 5-33; Ex. 1022 ('595 Application File History) at exhibit pages 1-29

According to the description in the priority documents to the '147 Patent, ***first*** the contact between bromine and activated carbon occurs, and ***then*** the "halogen/halide



"In-Flight" Sorbent Preparation

[0075] Furthermore, we have demonstrated that the halogen promoted carbon sorbent can be readily produced "in-flight". This is accomplished by, for example, contacting the vapors of any combination of halogens and optionally a second component, in-flight, with very fine carbon particles. The particles may be dispersed in a stream of transport air (or other gas), which also conveys the halogen/halide promoted carbon sorbent particles to the flue gas duct, or other contaminated gas stream, from which mercury is to then be removed. There is no particular temperature requirement for this contact. This technology is obviously very simple to implement, and results in a great cost savings to facilities using this technology for mercury capture.

promoted carbon sorbent particles" (i.e., the promoted bromine sorbent of claim 17) are transported ***to*** the mercury-containing gas.[379]

The "in-flight" promotion occurs on the way "to" the flue gas duct—before the sorbent contacts the mercury-containing gas.

a. The '163 and '595 Applications omit Substantial Portions of the Provisional

244. In addition to the reasons given above that the Provisional provides no disclosure of Claims 17-20, these portions of the Provisional were omitted from the '163 and the '595 Applications. For example, the '163 and '595 Applications omit the series of numbered "outline[s] of examples of the invention"—namely, the

[379] Ex. 1021 ('163 Application File History) at 20 ¶ [0075]; Ex. 1022 ('595 Application File History) at 16 ¶ [0075].

example number 1E in the Provisional referring to an "additional substance" is not carried over to the '163 and '595 Applications.[380]

245. Other portions from the Provisional were carried over to the '163 and the '595 Applications but were substantively changed. In particular, the text accompanying Figure 2 of the Provisional was changed as demonstrated by the redline below:[381]

~~FIG. 2 is a block diagram illustrating the use of the invention in a coal fueled facility. Of course, the invention can also be used in any other desired type of facility. FIG. 2 shows a boiler for burning pulverized coal. The facility utilizes various devices to clean the exhaust of the boiler.~~ In this example, a baghouse (fabric filter) or ESP ~~is~~was used to collect particulates in the exhaust of a full scale commercial pulverized coal burning facility. A scrubber and sorbent bed ~~re~~were also used to remove undesired constituents from the flue gas stream, before being fed to the stack. In ~~the~~this example ~~shown~~, the halogen/halide promoted carbon sorbent ~~is~~was injected into the flue gas after the boiler. ~~The additive~~In general however, the inventive sorbent can be injected where desired (e.g., before, after, or within the boiler).

As noted in the comparison above, the language of the '163 and the '595 Applications does not refer to an additive, but rather that the "***inventive sorbent*** can be injected where desired (e.g., before, after, or within the boiler.)"[382] Thus, the '163 and the '595 Applications merely describe injecting the sorbent (and only after the sorbent has been promoted with the halogen/halide) at various points in relation to the boiler.

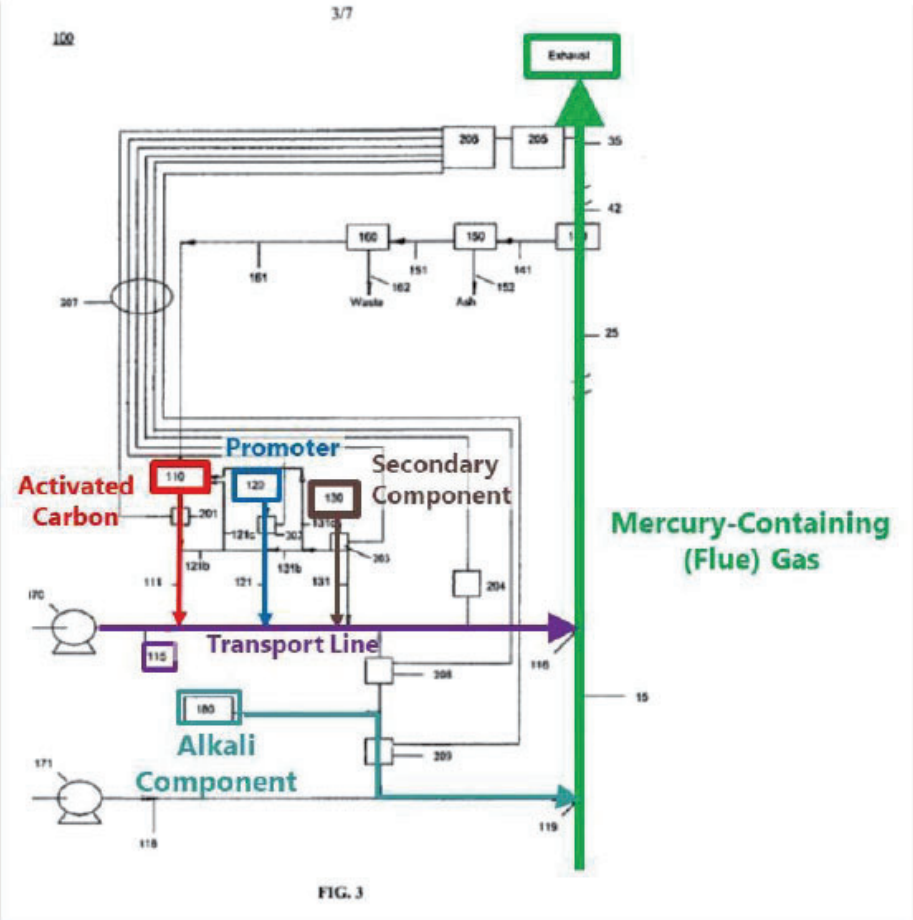
b. Figure 3 of the '163 and '595 Applications Does Not Disclose Claims 17-20

[380] *Compare* Ex. 1020 (Provisional) at exhibit pages 5-8, *with* Ex. 1021 ('163 Application File History) at exhibit pages 5-33, *and* Ex. 1022 ('595 Application File History) at exhibit pages 1-29.

[381] *Compare* Ex. 1020 (Provisional) at exhibit page 15, *with* Ex. 1021 ('163 Application File History) at ¶ [00107], *and* Ex. 1022 ('595 Application File History) at ¶ [00107].

[382] Ex. 1021 ('163 Application File History) at exhibit page 29 (¶ [00107]); Ex. 1022 ('595 Application File History) at exhibit page 25 (¶ [00107]).

246. The ’163 and ’595 Applications, with reference to Figure 3, repeat this timing of in-flight promotion occurring ***before*** injection into the mercury-containing gas. A transport gas is used to co-inject the bromine-containing promoter and sorbent material *from* the non-mercury-containing transport gas *into* the mercury-containing exhaust gas. The transport (purple) occurs before the mercury-containing gas (green). Fig. 3 from the ’163 and ’595 Applications is annotated below:[383]



[383] Ex. 1021 (’163 Application File History) at exhibit page 43 (Fig. 3) (annotated); Ex. 1022 (’595 Application File History) at exhibit page 42 (Fig. 3).

Figure 3 depicts four reservoirs: "base carbon reservoir 110" (red), "halogen/halide promoter reservoir 120" (blue), "second component reservoir 130" (brown), and "alkali component reservoir 180" (turquoise).[384] The reservoirs 110, 120, 130 "each connect through respective flow control devices and via associated piping, to transport line 115."[385] Transport line 115 is highlighted purple. "A source of air, nitrogen, or other transport gas(es) may be provided by gas source 170 to transport line 118 for the purpose of entraining materials discharged from reservoirs 110, 120, 130, and 180 and injecting such materials, via injection point 116, into contaminated flue gas stream 15."[386] Only the alkali component reservoir 180 is provided with a second independent "transport line 118" so that the alkali component "may be injected separately by transport line 118, combining [with the promoted carbon sorbent] downstream in flue gas 15."[387]

247. The halogen promoter is ***not*** provided with such a separate line. As shown in Fig. 3, the activated-carbon sorbent (110) and halogen promoter (120) are injected into the mercury-containing flue gas (15) ***together***, and ***not separately***, at point 116. In addition, neither Fig. 3 nor anything else in the '163 and '595

[384] Ex. 1021 ('163 Application File History) at exhibit page 14 (¶ [0054]); Ex. 1022 ('595 Application File History) at exhibit page 10 (¶ [0054]).
[385] Ex. 1021 ('163 Application File History) at exhibit page 14 (¶ [0055]); Ex. 1022 ('595 Application File History) at exhibit page 10 (¶ [0055]).
[386] Ex. 1021 ('163 Application File History) at exhibit page 14 (¶ [0055]); Ex. 1022 ('595 Application File History) at exhibit page 10 (¶ [0055]).
[387]

Applications discloses claim 19 of the '147 Patent. Instead, the only support for this embodiment recited in claim 19 is the language of claim 19 itself.

248. In addition to the embodiment of Figure 3, the '163 and '595 Applications provide two other specific embodiments in which the promoter and sorbent may be combined: in another line leading to the pneumatic transport line or within the activated carbon sorbent reservoir—both ***before*** (upstream of) introduction to the mercury containing (flue) gas:

> The halogen/halide may be combined and react with the base activated carbon according to any of several provided methods. The halogen/halide may preferably be combined via line 121 directly into transport line 115, within which it contacts and reacts with the base activated carbon prior to injection point 116. This option is one form of what is referred to herein as "in-flight" preparation of a promoted carbon sorbent in accordance with the invention. Further, the halogen/halide may be combined via line 121b with base activated carbon prior to entering transport line 115. Still further, the halogen/halide may be contacted and react with the base activated carbon by introduction via line 121c into reservoir 110.[388]

Critically, none of the multiple embodiments provided by '163 and '595 Applications disclose adding a bromine containing material anywhere other than to the activated carbon sorbent ***prior to*** injection into the mercury containing (flue) gas, such that the bromine-containing promoter is injected into the mercury-containing gas together with (and not separately from) the activated carbon.

Ex. 1021 ('163 Application File History) at exhibit page 16 (¶ [0062]); Ex. 1022 ('595 Application File History) at exhibit page 12 (¶ [0062]).

249. Notably, the descriptions of Figure 3 in the '163 and '595 Applications do recognize injecting "optional alkali component" 180, such as additives of base chemistry (Ca, Na, and others), into the flue gas separately from the activated carbon injection point, as indicated in purple above in annotated Figure 3.[389] While the inventors presumably considered it was important enough to specifically mention that an "optional alkali component" could be injected upstream using its own transport line to be "injected separately" resulting in the alkali component "combining downstream in flue gas 15" with activated carbon, at most, the applications refer to this embodiment as one where no halogen promotion occurs, such as where only an alkali component is used.[390] For example, Figure 10 compares "Standard AC" and "Standard AC with Alkali," where the alkali acts as a second sorbent to remove HCl, NOx, and other species in the flue gas so as to not foul any activated carbon.[391]

c. Figure 1 of the '163 and '595 Applications Does Not Disclose Claims 17-20

250. The other figures of the '163 and '595 Applications do not make up for the absence of any disclosure of injecting the bromine-containing promoter

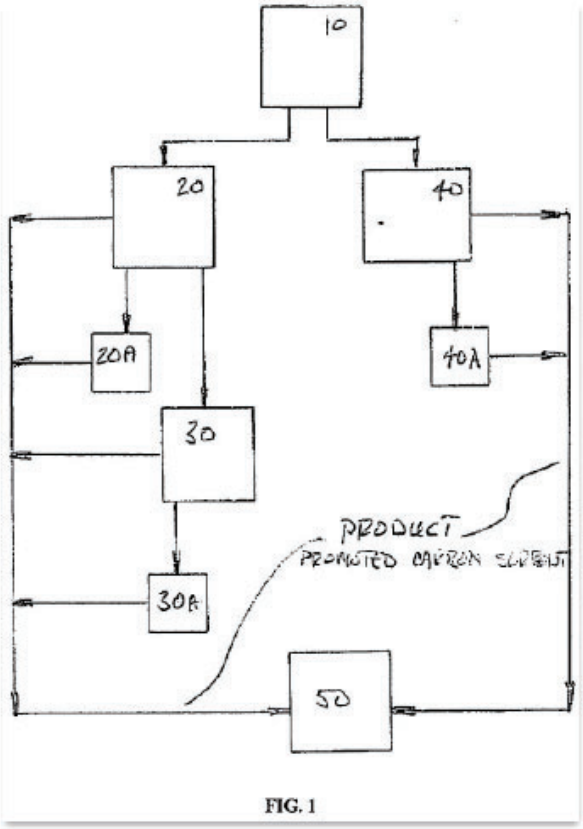
[389] Ex. 1021 ('163 Application File History) at exhibit page 16; Ex. 1022 ('595 Application File History) at exhibit page 12.

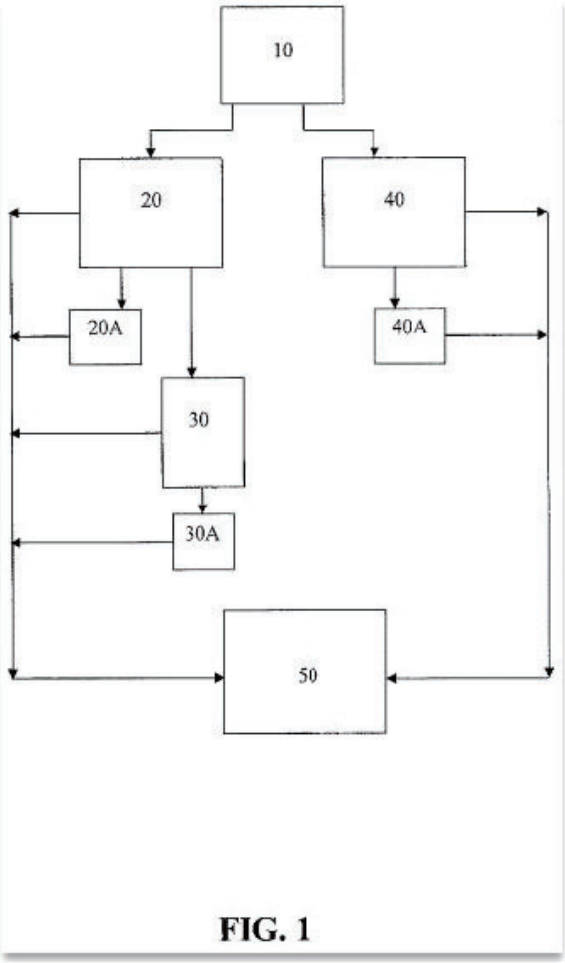
[389] Ex. 1021 ('163 Application File History) at exhibit page 16 (¶ [0061]); Ex. 1022 ('595 Application File History) at exhibit page 12 (¶ [0061]).

[390] Ex. 1021 ('163 Application File History) at exhibit page 16 (¶ [0061]); Ex. 1022 ('595 Application File History) at exhibit page 12 (¶ [0061]).

[391] Ex. 1021 ('163 Application File History) at Fig. 10, exhibit page 30 (¶ [00111]); Ex. 1022 ('595 Application File History) at Fig. 10, exhibit page 26 (¶ [00111]).

separately from injecting activated-carbon sorbent into a mercury containing (flue) gas stream (Claims 17-20 of the '147 Patent), or that the mercury-containing gas acts as a transport gas (claim 19 of the '147 Patent). None of them disclose an embodiment where a bromine containing promoter is injected into a mercury containing (gas) stream. Figure 1 from the '163 Application is shown to the left,[392] and Figure 1 from the '595 Application is shown to the right:[393]





[392] Ex. 1021 ('163 Application File History) at exhibit page 41.
[393] Ex. 1022 ('595 Application File History) at exhibit page 40.

251. The ’163 and ’595 Applications introduce, with reference to Figure 1, two embodiments for adding the base activated carbon (10) to a mercury-containing flue gas stream (50). First, Figure 1 identifies an embodiment along the left path, in which “block 10 illustrates providing a base activated carbon, and adding a halogen or halide promoter that reacts with the carbon, illustrated at block 20.”[394] Second, they identify another embodiment along the right path that includes “providing a base activated carbon as illustrated at block 10, and adding a halogen or halide promoter and a secondary component to the activated carbon together, with which they react as illustrated by block 40.”[395] These paths are shown below, in annotated Figure 1 from the ’595 Application.[396]

[394] Ex. 1021 (’163 Application File History) at exhibit page 12; Ex. 1022 (’595 Application File History) at exhibit page 8.
[395] Ex. 1021 (’163 Application File History) at exhibit page 12; Ex. 1022 (’595 Application File History) at exhibit page 8.
[396] Ex. 1022 (’595 Application File History) at exhibit page 40 (Fig. 1, annotated).

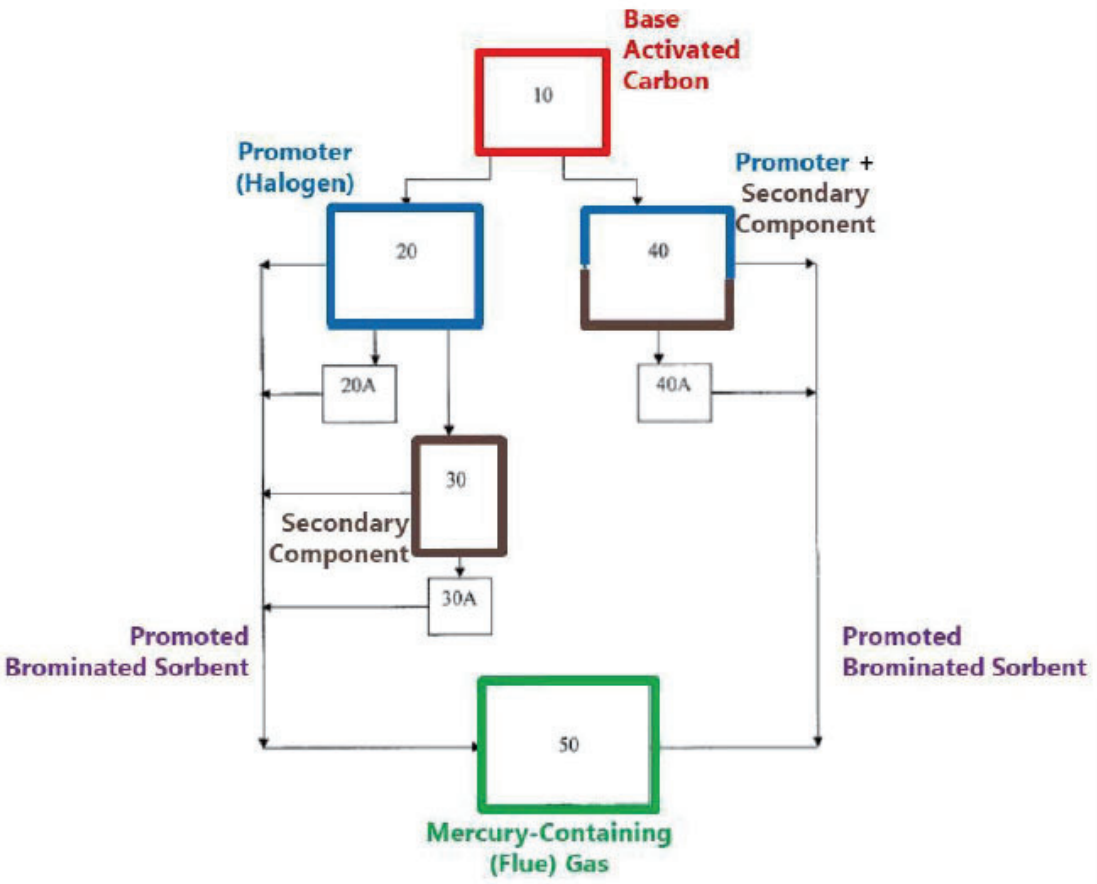

Base
Activated
Carbon
10
Promoter
(Halogen)
Promoter +
Secondary
Component
20
40
20A
40A
30
Secondary
Component
30A
Promoted
Brominated Sorbent
Promoted
Brominated Sorbent
50
Mercury-Containing
(Flue) Gas

FIG. 1

For both embodiments, the ’163 and ’595 Applications explain that block 50 is “a flue gas stream [that] is treated with product promoted carbon sorbent prepared as described above.”[397]

252. Whether through block 20 (left path) or block 40 (right path), both of these embodiments describe adding the halide promoter to the activated carbon and allowing them to react ***before*** introducing them to the flue gas, as represented by block 50. Accordingly, in both the first (left) embodiment and second (right) embodiment, the halide promoter and activated carbon sorbent are injected together into a transport line, and not “separately …” (as required by Claim 17 and its dependent claims) into the mercury-containing (flue) gas stream (as required by claim 18). I have reviewed the entirety of the ’163 and ’595 Applications and conclude there is no written-description support for injecting the halide promoter directly into the mercury-containing gas, separately from the activated carbon.

d. Replacement-Figure 1 Is Not Part of the Priority Analysis

253. Importantly, I understand that entitlement of Claims 17-20 to the priority claimed in the ’147 Patent must be judged based on the materials filed with the ’147 Patent or earlier. Replacement-Figure 1, as found in the issued ’147 Patent, is not the same as the version originally filed in the ’163 and ’595 Applications and

397

on April 6, 2009 with the ’219 Application. Figure 1, as originally filed on April 6, 2009 is reproduced below:[398]

254. This version of Figure 1 as filed with the original disclosure of the ’147 Patent is the same in substance to Figure 1 of the ’163 and ’595 Applications.

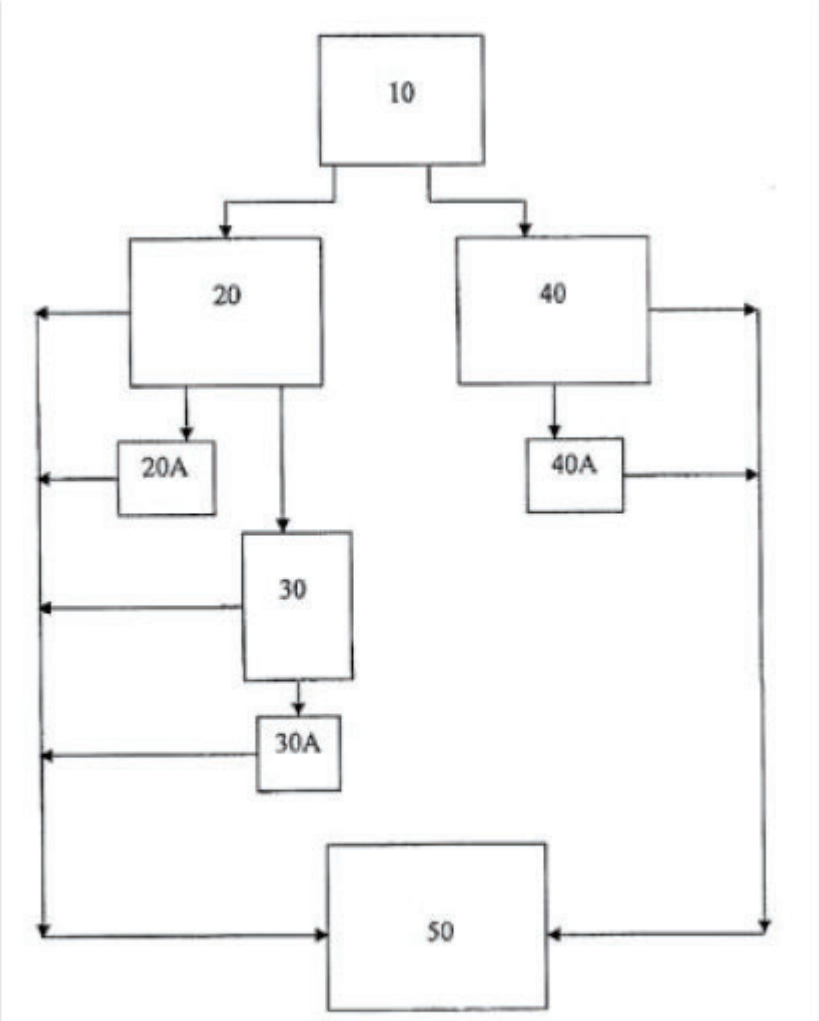


FIG. 1

The description of 1 in the ’163 Application and the ’595 Application, discussed above, is identical to that of the ’147 Patent, other than stylistic changes.[399] Importantly, the descriptions in the ’163 and ’595 Application are silent regarding any disclosure of a path directly from block 10 (activated carbon) to block 50 (flue gas).

255. After the initial filing of the ’219 Application, the USPTO issued a Notice to File Corrected Application Papers on September 4, 2009.[400] This notice requested corrections to Figures 2 and 4-10 of the application.[401] On December 4, 2009, the applicant filed a complete replacement set of Figures 1-10.[402] For purposes of comparison, the version of Figure 1 that was originally filed on April 6, 2009 with the ’147 Patent is shown on the left.[403] The revised version of Figure 1 that was filed on December 4, 2009 is shown on the right, with an annotation in yellow indicating the modification to the figure:[404]

Ex. 1021 (’163 Application File History) at exhibit page 13; Ex. 1022 (’595 Application File History) at exhibit page 9.

400 Ex. 1019 (’147 Patent File History) at 9.

400 *Compare*, Ex. 1021 (’163 Application File History) at ¶¶ [0043-51], *and* Ex. 1022 (’595 Application File History) at ¶¶ [0043-51], *with* Ex. 1001 (’147 Patent) at 6:40-7:60.

400 Ex. 1019 (“’147 Patent File History) at exhibit pages 69-70.

401 Ex. 1019 (“’147 Patent File History) at exhibit page 69.

402 Ex. 1019 (“’147 Patent File History) at exhibit pages 72-81.

403 Ex. 1019 (“’147 Patent File History) at exhibit page 9.

404 *Compare* Ex. 1001 (’147 Patent) at Fig. 1 (annotations provided in yellow), *with* Ex. 1019 (“’147 Patent File History) at exhibit page 9.

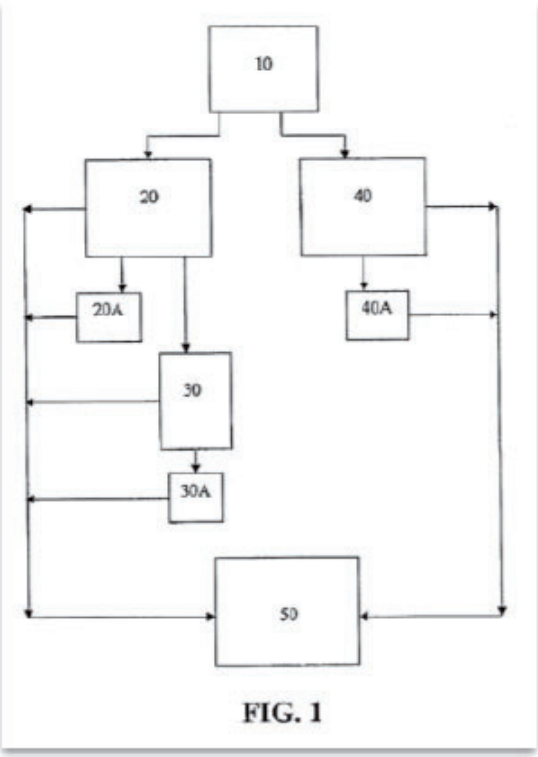


FIG. 1

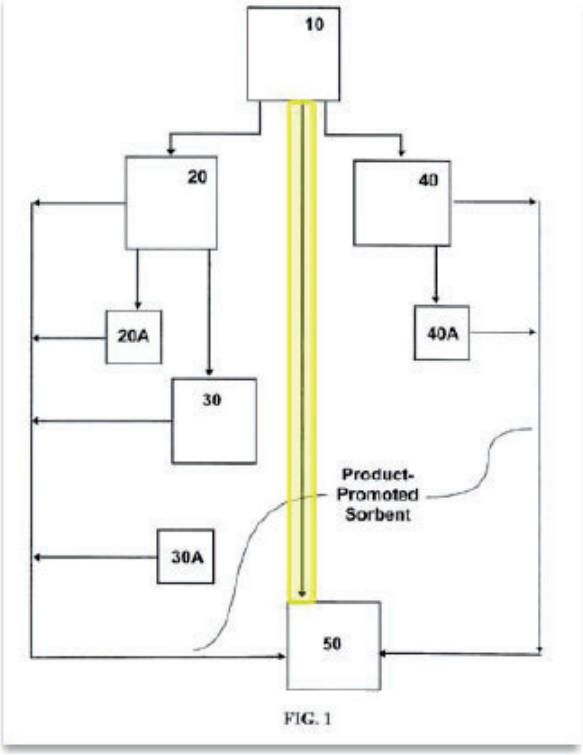
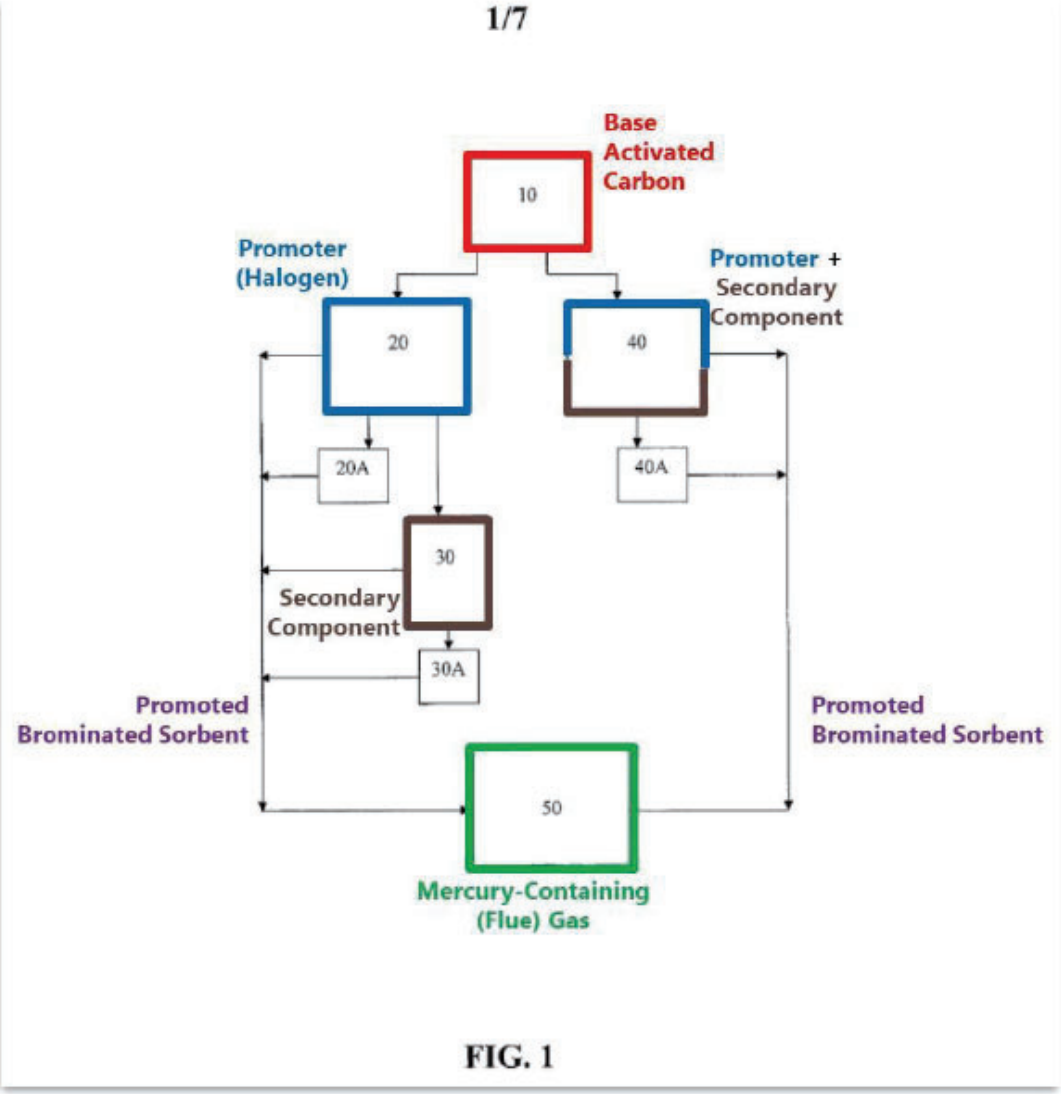


FIG. 1

As discussed above, this third path or embodiment (from block 10 to block 50) was added in the replacement drawing, and is not disclosed in the '219 Application as filed, or in the '163 and '595 Applications. Notably, the '163 and '595 Applications do not describe the embodiment identified by the middle path (highlighted above) of Figure 1, and the original Figure 1 in all these applications does not include that middle path.

256. Because there is no textual support describing the direct line between block 10 (activated carbon) and block 50 (flue gas), highlighted above in yellow, there is no support that the line added in Replacement-Figure 1 teaches adding activated carbon directly to the mercury-containing (flue) gas independently and

separately from the halide promoter as claimed in Claims 17-20. The '163 and '595 Applications display only the paths 10-20-30-50 and 10-40-50.[405]



Based on the explanation of these paths provided by the '163 and '595 Applications, a POSITA would be led to conclude that this unmentioned direct path added to Figure 1 of the '147 Patent between blocks 10 and 50 would be a simplified process

[405] Ex. 1022 ('595 Application File History) at exhibit page 40 (Fig. 1, annotated).

for treating a mercury-containing (flue) gas with a bromine-promoted carbon that is prepared before injection into the mercury containing (flue) gas, consistent with the other embodiments disclosed by the '163 and '595 Applications. Indeed, the only explanation given in the '163 and '595 Applications, or the '147 Patent itself, of what occurs at block 50 makes clear that this is a treatment of a mercury-containing (flue) gas with an already-prepared bromine promoted sorbent:[406]

> Referring still to FIG. **1**, also illustrated are preferred embodiments in which, as illustrated by block **50**, a flue gas stream is treated with product promoted carbon sorbent prepared as described above.

From this paragraph, the only conclusion that is left to be made from the direct line from 10 to 50 is that a flue gas is being treated with a product promoted carbon sorbent that has already been "prepared as described above" *(i.e.,* prepared, in the past-tense, prior to injection into the flue gas).

257. Even if PO could rely on this improperly-added line from box 10 (activated carbon) to box 50 (flue gas), it still fails to support Claims 17-19. At most, the specification refers to this embodiment as one where no halogen promotion occurs, such as where an alkali component is used instead of a halide promoter.[407]

[406]Ex. 1001 ('147 Patent) at 7:12-15 (emphasis added).

Figure 10 compares "Standard AC" and "Standard AC with Alkali," where the alkali acts as a second sorbet to remove HCl, NOx, and other species in the flue gas so as to not foul any activated carbon.[408] Accordingly, even Replacement-Figure 1 does not illustrate providing activated-carbon sorbent separately from bromine-containing promoter into a mercury-containing gas, with in-flight reaction occurring in the mercury-containing gas.

258. Based on this analysis, it is my opinion that Claims 17, 18, 19 and 20 of the '147 Patent do not find written-description support in any of the earlier applications preceding the '147 Patent.

259. As discussed above, the '147 Patent was filed on April 6, 2009 and claims priority through a chain of several earlier applications: U.S. Patent Application No. 12/201,595 filed on August 29, 2008 (the "595 Application"); U.S. Patent Application No. 11/209,163 (the "'163 Application"), filed on August 22, 2005 and which issued as U.S. Pat. No. 7,435,286 (the "'286 Patent"); and ultimately to the Provisional, filed August 30, 2004.

260. I have reviewed the specifications, figures, claims, and prosecution histories of the Provisional, the '163 Application, the '595 Application, and the '147 Patent. During my review, I specifically looked for any disclosure of: (a)

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[408] Ex. 1001 ('147 Patent) at 10:7-12; Fig. 10.
[408] Ex. 1001 ('147 Patent) at Fig. 10, 20:60-21:16.

injecting separately the sorbent material and bromine containing promoter into a mercury-containing gas stream; such that (b) in-flight reaction in the mercury-containing gas produces the promoted brominated sorbent, as required by claim 18 of the ’147 Patent. In addition, I also looked for any disclosure of the above in which the mercury-containing gas is also a transport gas, as required by claim 19 of the ’147 Patent.

261. I determined that none of the other applications between the Provisional and the filing of the ’219 Application—the application that led to the ’147 Patent—include any disclosure of Claims 17-20. The only disclosure of Claims 17-20 in the ’147 Patent, or any of the applications from which it claims priority, is found in the language of the claims themselves, which were first introduced in the April 6, 2009 preliminary amendment.

2. No Disclosure of Claims 17-20 in the Provisional

262. The disclosure of the Provisional does not cure the deficiencies of the ’147 Patent and its parent non-provisional applications.

263. The Provisional states: a “unique, nonobvious technique for preparation of the treated carbon is through combining the treatment system with the carbon injection system at the end-use site. With this technique, the halogen is introduced to the carbon-air mixture ***in the transport line (or other part of the***

sorbent storage and injection system)."[409] The halogen and activated carbon sorbent are, again, being combined in a transport line with a non-mercury-containing gas, and then injected together (not separately) into a mercury-containing gas.

264. I have also reviewed Figure 2 of the Provisional. First, I note that this figure does not appear in the '163 or '595 Applications. Figure 2 is reproduced below:[410]

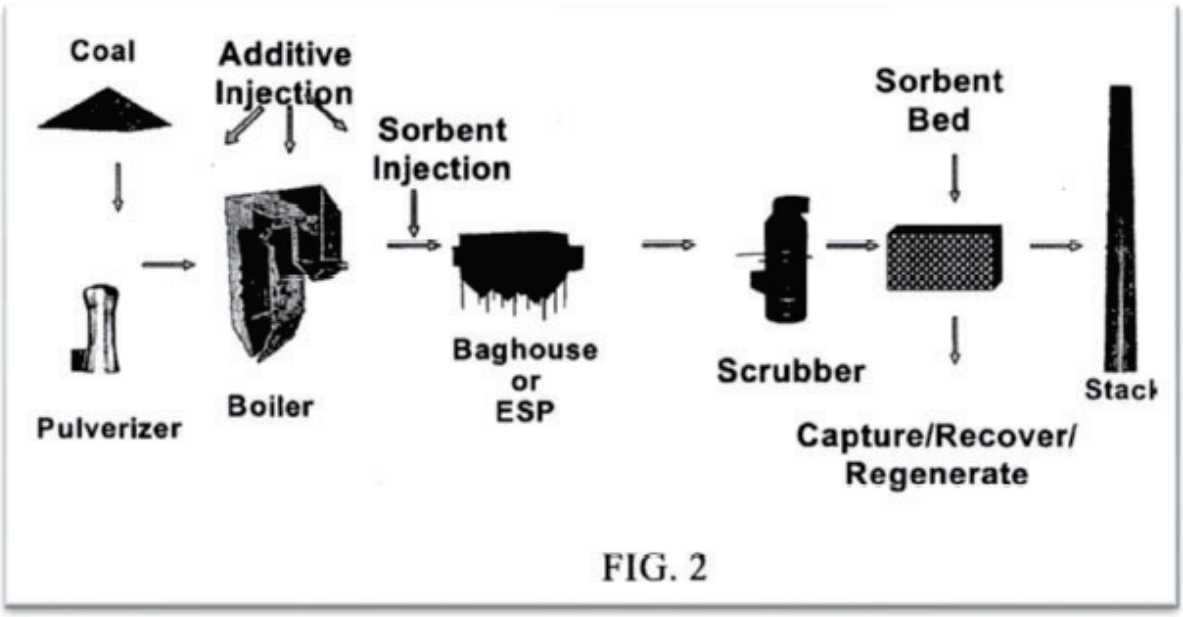


FIG. 2

Second, Figure 2 of the Provisional includes a label with "Additive Injection" having three arrows generically in the direction of the boiler of a coal-fired power plant.

[409] Ex. 1020 (Provisional) at exhibit page 14 (emphasis added).
[410] Ex. 1020 (Provisional) at Fig. 2.

The accompanying written description provides the only context of what is illustrated by this figure:[411]

DESCRIPTION OF EXEMPLARY EMBODIMENTS

FIG. 2 is a block diagram illustrating the use of the invention in a coal fueled facility. Of course, the invention can also be used in any other desired type of facility. FIG. 2 shows a boiler for burning pulverized coal. The facility utilizes various devices to clean the exhaust of the boiler. In this example, a baghouse or ESP is used to collect particulates in the exhaust. A scrubber and sorbent bed are also used to remove undesired constituents from the flue gas stream, before being fed to the stack. In the example shown, the sorbent is injected into the flue gas after the boiler. The additive can be injected where desired (e.g., before, after, or within the boiler).

265. Where the Provisional refers to the additive, it describes that these are "additives of base chemistry" that are "comprised of Group I or Group II elements, such as Ca, Na, and others."[412] These additives are explained in more

9. The process of using additives (1-8) in conjunction with sorbents to capture acid gases and other flue gas constituents that block oxidation reactions or consume sorbent sites that would otherwise capture mercury. The additive is a compound comprised of Group I or II elements, such as Ca, Na, and others. These additives of base chemistry may be added to flue gas as a sorbent mixture or co-injected to selectively sorb acid gases or other gas constituents that compete for mercury reactive/sorption sites, thereby improving the effectiveness of activated carbon to capture mercury. In addition, the base additives can augment the treated activated carbon by helping to capture oxidized mercury forms in the flue gas, such as mercuric chloride, or that are produced on the carbon sorbent, such as mercuric bromide, but are released to the gas phase as the sorbent becomes saturated or capacity limited.

Ex. 1020 (Provisional) at exhibit page 16 (Fig. 2).

412 Ex. 1020 (Provisional) at exhibit page 15 (emphasis added).

412 Ex. 1020 (Provisional) at exhibit page 4 (Abstract).

detail by "outline of examples of the invention" number 9, reproduced below as annotated:[413]

Halogens (including bromine) are in Group VII, and not Groups I or II. This makes clear that the "additive" disclosed by the Provisional is not the bromine-containing promoter itself, but is instead a non-bromine based additive of base chemistry of Ca (Calcium), Na (Sodium), or other alkali—those elements in the first two groups (columns) of the periodic table. The primary function recognized by this alkali additive is to neutralize other contaminants within the flue gas that would otherwise "compete for mercury reactive/sorption sites."[414] Crucially, in this paragraph the Provisional does not describe the "additive" chemically reacting with the active-carbon sorbent (as would be required by claim 1 of the '147 Patent for a bromine-containing promoter). And, as emphasized above, this additive is used to "augment the treated activated carbon"—the "treated activated carbon" meaning that it had already been treated (promoted) by the time the additive is applied. The additive does not provide an in-flight reaction promoting the sorbent with a bromine-containing promoter within the mercury-containing (flue) gas stream.

266. Based on this analysis, it is my opinion that Claims 17-20 of the '147 Patent do not find written-description support in any of the earlier applications

413 Ex. 1020 (Provisional) at exhibit page 7 (emphasis added).

preceding the '147 Patent and that their support is found in the introduction of those claims on April 6, 2009.

B. PRIORITY ANALYSIS FOR THE '114 PATENT

267. I have been asked to review the '114 Patent, and its earlier filed parent applications, from the perspective of a POSITA and to look for support for the claims of the '114 Patent. I understand from the family tree[415] that the '114 Patent was filed through a series of patent applications back to the Provisional, filed on August 30, 2004. I have been informed that, in order for a patent claim to be entitled to the priority date of an earlier-filed application, each and every element of that claim must be fully supported by the disclosure of both: (a) the earlier-field application; and (b) all intervening applications in the chain.

268. I have reviewed the '114 Patent and its file history, and that of its parent applications. I have determined that prior to the filing date of the '114 Patent in May 2018, a person of skill in the art would not have concluded that the applicants were in possession of the full subject matter recited in the issued claims of the '114 Patent.

269. As I explain below, there are multiple limitations in each of the issued claims of the '114 Patent claims that are not disclosed in all of the earlier-filed applications. These include limitations missing from each independent claim (claims 1, 23, 24, 25), such as the limitations below:

[415] Ex. 1017 (Family Tree).

- "the coal comprises added Br 2, HBr, Br^-, or a combination thereof, added to the coal of the combustion chamber" (claims 1, 23, 24) and "the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber" (claim 25);
- "the combustion chamber comprises added Br_2, HBr, Br-, or a combination thereof" (claims 1, 23, 24) and "the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof" (claim 25);
- the coal or combustion chamber comprising "added Br_2, . . . Br-, or a combination thereof" (claims 1, 23, 24), and the coal or combustion chamber comprising "added Br_2, . . . a bromide compound, or a combination thereof" (claim 25).

In the subsections below, I explain why each of these limitations were not present in the '594 Application (filed Oct. 17, 2016), which is the immediate parent of the '114 Patent. I also explain why these limitations were not present in intervening patent applications. I then explain (to the extent it is considered relevant to the analysis) limitations missing from the Provisional (filed Aug. 30, 2004), which is the earliest application to which the '114 Patent purports to claim priority.

9. The Passages Cited by the Applicants for Support During Prosecution of the '114 Patent Were Added Through Later Continuations-In-Part

270. As described above, on March 20, 2019, the applicants amended the sole independent claim and added three new independent claims to the '760 Application (which ultimately issued as claims 1, 23, 24, and 25 of the '114 Patent) to recite certain bromine-containing species being added to the combustion chamber

or to the coal upstream of the combustion chamber.[416] The applicants further amended claim 7 of the '760 Application to recite that "the coal comprises added Br_2, HBr, Br-, or a combination thereof, added to the coal upstream of the combustion chamber."[417] In support of these amendments, the applicants cited to paragraphs [0088], [0123]–[0125], [0138], [0144], [0155], and [0164] and Figure 6 of the '760 Application.'[418]

271. I reviewed each of the above-cited portions of the '760 Application that the applicants cited. With the exception of paragraph [0088], each of these paragraphs was added in the continuation-in-part '760 Application filed May 14, 2018. This can be seen in Exhibit 1068, which is a redline comparison between the '760 Application and the '594 Application (the immediate parent of the '760 Application).[419] This is further evidenced by the fact that the last paragraph of the '594 Application is paragraph [01091.[420] Figure 6 of the '114 Patent was also added on May 14, 2018, and is not present in the '594 Application. [421] Paragraph [0088] of the '760 Application was present in the '594 Application,'[422] but it discusses the surface structure of activated carbon and its interaction with halogens.

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[416] Ex. 1026 ('114 Patent File History) at exhibit pages 1905-11.
[417] Ex. 1026 ('114 Patent File History) at exhibit pages 1906.
[418] Ex. 1026 ('114 Patent File History) at exhibit page 1824; see Ex. 1026 ('114 Patent File History) at 38-49, 62.
[419] Ex. 1068 (Redline Comparison, Showing changes from '594 Application (as published at 2017/0128908) to '760 Application (as published at 2018/0257031)).
[420] Ex. 1025 ('594 Application File History) at 37 (Originally Filed Application).
[421] Ex. 1025 ('594 Application File History) at exhibit pages 43-47 (Originally Filed Drawings).
[422] Ex 1025 ('594 Application File History) at 30 ¶ [0087].

It does not describe bromine-containing species being added to either the combustion chamber, the coal, or anywhere else.[423] Thus, the paragraphs identified by applicants from the '760 Application as supporting the independent claims (other than paragraph [0088]) were not present in the family of the '760 Patent Application prior to May 14, 2018. And as discussed further below regarding the Provisional, to the extent one considered the disclosure in that filing, even those paragraphs do not fully support the claims of the '114 Patent.

272. I have also reviewed the portion of the '760 Application cited by applicants in support of its amendments regarding claim 7. On May 15, 2018, the applicants added claim 7 to the '760 Application, which recites "wherein a promoter precursor is on the coal, wherein the combusting of the coal forms the halogen or halide promoter in the mercury-containing gas."[424] On December 3, 2018, following a rejection for lack of written description, the applicants amended claim 7 to recite, "wherein the coal comprises added Br_2, HBr, Br-, or a combination thereof."[425] In arguing written description support for dependent claim 7 as amended, the applicants cited to paragraphs [0035], [0050], [0064], [0088], [0098]-[0107], and Figure 6.[426]

273. I reviewed the portions of the '760 Application (the second continuation-in-part in the chain of patents) cited by the applicants in support of

[423] Ex. 1026 ('114 Patent File History) at 30.
[424] Ex. 1026 ('114 Patent File History) at exhibit pages 75-79 (5/15/2018 Preliminary Amendment).
[425] Ex. 1026 ('114 Patent File History) at exhibit page 1646.
[426] Ex. 1026 ('114 Patent File History) at exhibit page 1648 (12/3/2018 Resp. to Office Action).

claim 7 of the ’760 Application[427]and have also reviewed the corresponding portions of the ’058 Application (the first continuation-in-part in the chain of patents filed April 23, 2009), as originally filed. First, as described above, Figure 6 of the ’114 Patent was also added on May 14, 2018, and is not present in the ’594 Application.[428] Second, paragraphs [0050], [0064], and [0088] of the ’760 Application simply describe the characteristics of a promoted sorbent and a mechanism for how it reacts with mercury, but do not describe any bromine-containing species being added to either the combustion chamber, the coal, or anywhere else. Third, paragraphs [0098]–[0107] of the ’760 Application merely refer to a halogen promoter being contacted with a base sorbent in a flue gas, but again do not refer to any bromine-containing species being added to the combustion chamber or coal.[429] I also note that paragraph [0098], as found in the ’760 Application was amended significantly in April 2009 in the ’ 058 Application, as shown below:

[427] Ex. 1026 (’114 Patent File History) at exhibit page 1648 (12/3/2018 Resp. to Office Action); Ex. 1026 (’114 Patent File History) at 18-33, 62 (Originally Filed U.S. Patent Application No. 15/978,760).
[428] Ex. 1025 (’594 Application File History) at exhibit pages 43-47 (Originally Filed Drawings).
[429] Ex. 1026 (’114 Patent File History) at 33.

’760 Application (as filed May 14, 2018)[430]

Advantages of On-Site Preparation

[0098] In-flight preparation of the halogen/halide-promoted sorbent on location produces certain advantages. For example, the treatment system can be combined with the base sorbent injection system at the end-use site. With this technique, the halogen/halide is introduced to the base sorbent air (or other gas, including to the flue gas or other mercury containing gas) mixture in a transport line (or flue gas duct part of the base sorbent storage and injection system). This provides the following benefits over current conventional concepts for treating sorbents off-site:

Changes from ’058 Application (as filed Apr. 23, 2009)[431] to ’760 Application[432]:

Advantages of On-Site Preparation

[~~0099~~0098] In-flight preparation of the halogen/halide-promoted sorbent on location produces certain advantages. For example, the treatment system can be combined with the base sorbent injection system at the end-use site. With this technique, the halogen/halide is introduced to the base sorbent air (or other gas, including to the flue gas or other mercury containing gas) mixture in a transport line (or flue gas duct part of the base sorbent storage and injection system). This provides the following benefits over current conventional concepts for treating sorbents off-site:

Changes from ’595 Application (filed Apr. 29, 2008) to ’058 Application (as filed Apr. 23, 2009):[433]

[~~0078~~0099] In-flight preparation of the halogen/halide -promoted ~~carbon~~ sorbent on location produces certain advantages. For example, the treatment system can be combined with the ~~carbon~~base sorbent injection system at the end-use site. With this technique, the halogen/halide is introduced to the ~~carbon~~ base sorbent air (or other gas, including to the flue gas or other mercury containing gas) mixture in a transport line (or ~~other~~flue gas duct part of the base sorbent storage and injection system). This provides the following benefits over current conventional concepts for treating sorbents off-site: [~~0079~~0100] Capital equipment costs at a treatment facility are

[430] Ex. 1026 (’114 Patent File History) at 33 ¶ [0098].
[431] Ex. 1023 (’058 Application File History) at 24.
[432] Ex. 1069 (Redline Comparison, Showing changes from ’058 Application (as published at 2009/0297413) to ’760 Application (as published at 2018/0257031)).
[433] Ex. 1064 (Redline Comparison, showing changes from ’595 Application (as published at 2009/0062119) to ’058 Application (as published at 2009/0297413))

274. Last, while paragraph [0035] of the '760 Application does state that "the promoter is introduced into the mercury-containing gas upstream of the introduction of base sorbent,"[434] it does not state how far upstream of the base sorbent the promoter is injected, or whether the promoter is introduced upstream or downstream of the combustion chamber. Paragraph [0035] does not refer to bromine-containing species being added to the combustion chamber or the coal. I also note that this entire paragraph was first added by the continuation-in-part '058 Application when filed April 23, 2009.[435]

10. There Is No Support for the '114 Patent Claim Limitations in the Provisional

275. As described above, the applicants copied and pasted the contents of the Provisional into the '760 Application when they filed the '760 Application.[436] Earlier applications in the priority chain of the '760 Application had not explicitly included the contents of the '640 Provisional, and had only included a generic statement of incorporation by reference. I am informed that, as a legal matter, this is insufficient to permit consideration of that material for a priority analysis. However, even if a person of ordinary skill in the art were to consider the technical

[434] Ex. 1026 ('114 Patent File History) at 18.
[435] Ex. 1064 (Redline Comparison, Showing changes from '595 Application (as published at 2009/0062119) to '058 Application (as published at 2009/0297413)) at ¶ [0037]; Ex. 1026 ('114 Patent File History) at 18 ¶ [0035] (original '760 Application).
[436] Ex. 1068 (Redline Comparison, Showing changes from '594 Application (as published at 2017/0128908) to '760 Application (as published at 2018/0257031)).

disclosures the Provisional, the Provisional would fail to disclose limitations from the issued claims of the '114 Patent.

a. Adding Br-Containing Components to Coal

276. The passages cited by the applicants during prosecution of the '760 Application in support of the claims do not, by themselves or collectively, support the limitations from issued claims 1, 23, 24, and 25 of the claims of the '114 Patent that "the coal comprises added" bromine-containing species.

277. Where the applicant cited paragraph [00164] that the "additive can be injected where desired (e.g., before, after, or within the boiler),"[437] a person of ordinary skill in the art would not conclude that this necessarily discloses the "additive" being added to the coal.'[438] Paragraph [00164] originates from the Provisional and, other than referring to corresponding Figure 2, is identical to the language of the Provisional reproduced below as emphasized: [439]

DESCRIPTION OF EXEMPLARY EMBODIMENTS

FIG. 2 is a block diagram illustrating the use of the invention in a coal fueled facility. Of course, the invention can also be used in any other desired type of facility. FIG. 2 shows a boiler for burning pulverized coal. The facility utilizes various devices to clean the exhaust of the boiler. In this example, a baghouse or ESP is used to collect particulates in the exhaust. A scrubber and sorbent bed are also used to remove undesired constituents from the flue gas stream, before being fed to the stack. In the example shown, the sorbent is injected into the flue gas after the boiler. The additive can be injected where desired (e.g., before, after, or within the boiler).

[437] Ex. 1026 ('114 Patent File History) at exhibit page 1824; see Ex. 1026 ('114 Patent File History) at 39-40 ¶ [00164].
[438] Ex. 1026 ('114 Patent File History) at exhibit pages 1648, 1824.
[439] Ex. 2016 ('760 Application) at 39-4011 [00164]; Ex. 1020 (Provisional) at p. 12 (emphasis added), p. 15.

Likewise, the illustration associated with this description appears as Figure 2 of the Provisional (and Figure 6 of the '114 Patent), as reproduced below: [440]

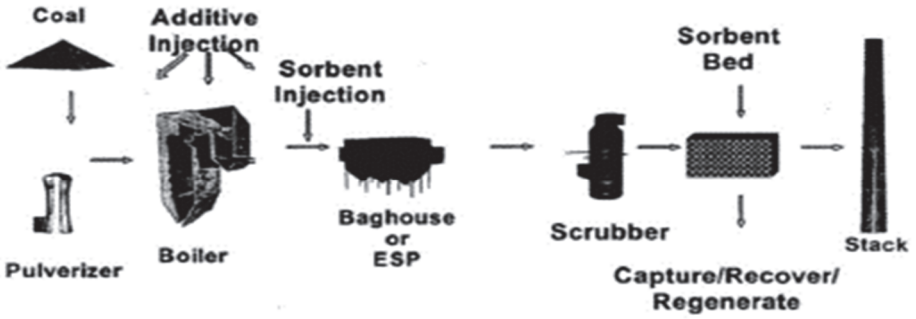


FIG. 2

278. This Figure 2 of the Provisional and corresponding Figure 6 of the '114 Patent includes a label with "Additive Injection" having three arrows pointing generically in the direction of the boiler of a coal-fired power plant. Even if "the additive can be injected" were to refer to injecting a Br-containing promoter—as opposed to injecting an alkali component used to capture "acid gases or other [flue] gas constituents"[441]—paragraph [0164] in the ' 760 Application (and corresponding language in Provisional) does not support adding the additive "to the coal." A POSITA would not necessarily understand that injecting an additive "before . . . the boiler" involves adding the promoter to the coal, as there are a number of systems

[440] Ex. 1020 (Provisional) at Figure 2; Ex. 1001 ('114 Patent) at Figure 6.
[441] Ex. 1020 (Provisional) at p.7 (item 9: "additives of base chemistry").

ahead of the boiler that do not interface with coal—including secondary-air systems and/or low-NOx overfire air systems.[442] Injecting an additive "before . . . the boiler" could also involve a specialized additive injection system leading to the boiler, that does not interact with the coal before being introduced to the combustion chamber.

279. Accordingly, Figure 2 and its accompanying text in the '640 Provisional (and paragraph [0164] and Figure 6 of the '760 Application) fails to clearly disclose that "*the coal* comprises added" bromine-containing species, as required by each of the independent claims of the '114 Patent.

b. No Disclosure of a Promoter Comprising Br_2, Br^-, or Combinations of Br_2 and HBr with Bromide Compounds in the Earlier-Filed Patent Applications

280. The Provisional also does not disclose:

- the coal or combustion chamber comprising "added Br_2, . . . Br^-, or a combination thereof'' (claims 1, 23, 24); and
- the coal or combustion chamber comprising "added Br_2, . . . a bromide compound, or a combination thereof'' (claim 25).

281. In addition to not disclosing adding any bromine-containing species to the coal (as discussed above), the Provisional also fails to disclose adding to the coal or to the combustion chamber the particular bromine-containing species recited in the claims of the '114 Patent. Regarding Paragraphs [00124]-[00125] of the '760

[442] Ex. 1027 (B&W: Steam) at 13-3

Application and corresponding text in the Provisional, Example 1 E recites that the "additional substance is hydrohalide (HI, HBr, HCl), etc., 1% B-10% of bromine."[443]

282. First, as explained above, the Provisional refers to an "additional substance" rather than an "additive."[444] But even if the "additional substance" of a bromine-based chemical were to include hydrogen bromide (HBr) (as per example 1E), a POSITA would understand that, as confirmed by the declaration of one of the inventors, John Pavlish, submitted on March 20, 2019 during prosecution of the '114 Patent, "hydrogen bromide" is defined as "the diatomic molecule with the formula HBr. It is a colorless compound and a hydrogen halide."[445] This is different than the Br_2, Br^-, and bromine compound recited in the claims of the '114 Patent.

283. The Provisional does not disclose that "the coal comprises added Br_2" or that "the combustion chamber comprises added Br_2" as is required in all of the independent Claims 1, 23, 24, and 25 of the '114 Patent. As admitted by Dr. Pavlish during prosecution of the '114 Patent, "[h]ydrogen halides have different properties than elemental halogens and are therefore different compounds. . . . Hydrogen halides are not part of and cannot be extracted or isolated from elemental halides; rather, only via a chemical reaction that results in a chemical and structural change

[443] Ex. 1020 (Provisional) at p. 3 (Example 1E); Ex. 1026 ('114 Patent File History) at 29-30 (¶¶ [00123-25]).
[444] Ex. 1020 (Provisional) at p. 3.
[445] Ex. 1026 ('114 Patent File History) at exhibit pages 1785-86 ¶ 12 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

can hydrogen halides be formed from elemental halides."[446] As Dr. Pavlish stated more succinctly: "Br_2 is not HBr and does not include HBr."[447] Thus, the Provisional does not disclose adding Br_2 to the combustion chamber or to the coal.

284. A disclosure of HBr in the Provisional also does not necessarily disclose that "the coal comprises added Br^-" or that "the combustion chamber comprises added Br^-," as is required in independent Claims 1, 23, and 24 of the '114 Patent. As Dr. Pavlish stated in his declaration, Br^- refers to "a bromine atom with an ionic charge of -1 (Br^-)," as opposed to "bromide" which is "a binary compound of bromine with another element or a radical."[448] Thus, to POSITA reviewing the Provisional would not have concluded that the use of HBr necessarily disclosed that "the coal comprises added Br."

285. Last, a disclosure of HBr in the Provisional does not support that the coal and/or combustion chamber includes added "bromide compound[s]," as required by Claim 25. Indeed, there are a nearly infinite number of forms of bromide compounds, because as stated by Dr. Pavlish, a "bromide compound" may be any "chemical compound containing a bromide ion or ligand."[449] Thus, a disclosure in

[446] Ex. 1026 ('114 Patent File History) at exhibit page 1787¶17 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).
[447] Ex. 1026 ('114 Patent File History) at exhibit page 1787 ¶ 17 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).
[448] Ex. 1026 ('114 Patent File History) at exhibit page 1784 ¶ 9 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).
[449] Ex. 1026 ('114 Patent File History) at exhibit page 1784 ¶ 9 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

the Provisional of a particular type of chemical (HBr) does not demonstrate that the inventors were in possession of the broad class of chemicals of any "bromide compound."

11. The ' 595 Application (Filed Aug. 29, 2008) also does not support the '114 Claims

286. I have also reviewed the ' 595 Application, as originally filed August 29, 2008.[450] Figure 6 of the '114 Patent, and the paragraphs cited by the applicants during prosecution of the '114 Patent as support for their amended '114 Patent claims,[451] were either not present or substantially amended between the ' 595 Application and the ' 760 Application.[452] A POSITA would not understand anything in the text or figures of the ' 595 Application to disclose the following limitations from the '114 Patent:

- "the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal of the combustion chamber" (claims 1, 23, 24) and "the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber" (claim 25);
- "the combustion chamber comprises added Br_2, HBr, Br-, or a combination thereof' (claims 1, 23, 24) and "the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof'' (claim 25);
- the coal or combustion chamber comprising "added Br_2, . . . Br-, or a combination thereof'' (claims 1, 23, 24) and the coal or combustion chamber

[450] Ex. 1022 ('595 Application File History) at p. 1-29 (Description), p. 30-33 (Claims), p. 34 (Abstract).
[451] Ex. 1026 ('114 Patent File History) at exhibit page 1824; *see* Ex. 1026 ('114 Patent File History) at 38-49, 62.
[452] Ex. 1066 (Redline Comparison, Showing changes from '595 Application (as published at 2009/0062119) to '760 Application (as published at 2018/0257031)); *see also* Ex. 1063 (Redline Comparison, Showing changes from '163 Application (as published at 2006/0048646) to '760 Application (as published at 2018/0257031)).

comprising "added Br_2, . . . a bromide compound, or a combination thereof" (claim 25).

In particular, nothing in the '595 Application discloses adding a bromine-containing species in the combustion chamber or to the coal, let alone the specific types of bromine-containing species recited in the '114 Patent claims. This is because the '595 Application is directed to preparing a brominated activated carbon outside of the mercury-containing flue gas, and then injecting the brominated sorbent into the mercury-containing flue gas downstream from the combustion chamber. Nothing in the '595 Application describes adding the bromine promoter independently from the mercury sorbent, let alone to the coal or combustion chamber.

12. The ' 594, ' 896, and ' 058 Applications in the '114 Chain also Do Not Support the '114 Claims

287. As shown in the family tree provided above,[453] the '114 Patent claims priority as a continuation-in-part application to the ' 594 Application (filed Oct. 17, 2016). The ' 594 Application[454] is a continuation of the ' 896 Application (filed Dec. 11, 2013),[455] which is a continuation of the ' 058 Application (filed Apr. 23, 2009).[456] The figures and description (i.e., everything other than the claims) are substantively identical between the ' 594, ' 896, and ' 058 Applications. Figure

[453] Ex. 1017 (Family Tree).
[454] Ex. 1025 ('594 Application File History).
[455] Ex. 1024 ('896 Application File History).
[456] Ex. 1023 ('058 Application File History).

6 of the ’114 Patent, and the paragraphs cited by the applicants during prosecution of the ’114 Patent as support for their amended ’114 Patent claims,[457] were not present in any of the ’594, the ’896, or the ’058 Applications.[458]

288. I note that Claims 5, 11, and 18 of the ’594 Application (as filed Oct. 17, 2016) and the ’896 Application (as filed Dec. 11, 2013) do recite that “halogen or halide promoter is introduced *into at least one of before a combustion chamber* that produces a mercury-containing gas, *into a combustion chamber* that produces a mercury-containing gas . . .”[459] First, these claims are not present in the ’058 Application that was filed on Apr. 23, 2009.[460] Second, as described above regarding Figure 2 of the Provisional, a person of ordinary skill in the art would understand that introduction of a promoter before the combustion chamber would not necessarily refer to adding that promoter to the coal. For example, the promoter could be introduced into any number of systems upstream of the combustion chamber that do not interface with coal—such as a secondary air system, a low-NOx overfire air system, or potentially even a specialized dedicated additive

[457] Ex. 1026 (’114 Patent File History) at exhibit page 1824; see Ex. 1026 (’114 Patent File History) at 38-49, 62.
[458] See, e.g., Ex. 1068 (Redline Comparison, Showing changes from ’594 Application (as published at 2017/0128908) to ’760 Application (as published at 2018/0257031)); Ex. 1065 (Redline Comparison, Showing changes from ’058 Application (as published at 2009/0297413) to ’594 Application (as published at 2017/0128908)).
[459] Ex. 1025 (’594 Application File History) at 29-32 (emphasis added); Ex. 1024 (’896 Application File History) at 29-32.
[460] Ex. 1023 (’058 Application File History) at 29-32.

injection system having a nozzle directly into the boiler.[461] Nothing in the remainder of these applications describe adding a promoter to the coal.

289. The ’594, ’896, and ’058 Application do include new Figures 5A and 5B (not present in the ’595 Application filed Aug. 29, 2008) that are reproduced below: [462]



FIG. 5A



FIG. 5B

Figures 5A and 5B and their newly added descriptions in the specification provide the first arguable support for any embodiment where the bromide promoter is introduced independently from the sorbent into the combustion chamber or the flue gases:

[461] Ex. 1027 (B&W: Steam) at 13-3.
[462] Ex. 1023 (’058 Application File History) at exhibit page 44.

> Injection streams 401, 402, 403 and 404, in addition to stream 501, are multiple locations wherein promoter, base sorbent, or a combination of promoter and base sorbent may be introduced.[463]
>
> * * *
>
> In an embodiment, a promoter is introduced to chamber 301 at location 401. A base sorbent (carbon, non-carbon, or their combination) is introduced at location 402 upstream of air heater 302.[464]

However, as previously described, where the arrows 401/401' and 501/501' of Figures 5A and 5B illustrate "streams" that originate outside of the boiler, this again does not necessarily describe to a POSITA that "the coal comprises added" bromine promoter. For example, in Figures 5A and 5B, the promoter could be added to the combustion chamber by first introducing the promoter into any one of the multitude of auxiliary systems located upstream of the combustion chamber (e.g., secondary air systems, low NOx overfire air systems, or a specialized promoter injection system), which do not necessarily add the promoter to the coal.

290. Accordingly, the '594, '896, and '058 Applications fail to disclose the following claim limitations of the '114 Patent:

- "the coal comprises added Br_2, HBr, Br-, or a combination thereof, added to the coal of the combustion chamber" (claims 1, 23, 24) and "the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber" (claim 25),

[463] Ex. 1023 ('058 Application File History) at 22-23 ¶ [0092].
[464] Ex. 1023 ('058 Application File History) at 23 ¶ [0095].

- the coal or combustion chamber comprising "added Br_2, . . . Br-, or a combination thereof" (claims 1, 23, 24) and the coal or combustion chamber comprising "added Br_2, . . . a bromide compound, or a combination thereof" (claim 25).

C. PRIORITY ANALYSIS FOR THE '225, '430, AND '517 PATENTS

291. I understand from the family tree that the '225, '430, and '517 Patents claim priority through a chain of several earlier continuation applications and ultimately to the Provisional: the '517 Patent is a continuation of the '430 Patent, which is a continuation of the 15/951,970 application (now U.S. Patent No. 10,933,370), which is a continuation of the '225 Patent, which is a continuation of the 14/318,270 application (now U.S. Patent No. 9,757,689), which is a continuation of the 13/966,768 application (now U.S. Patent No. 8,821,819), which is a continuation of the 13/427,665 application (now U.S. Patent No. 8,512,655), which is a continuation of the '147 Patent, which is a continuation of the 12/201,595 application, which is a divisional of the 11/209,163 application, which claims priority to the Provisional, filed August 30, 2004.[465]

292. I have been informed that, in order for a patent claim to be entitled to the priority date of an earlier-filed application, each and every element of that claim must be fully supported by the disclosure of both: (a) the earlier-filed application; and (b) all intervening applications in the chain. Therefore, I have evaluated the

[465] '517 ADS (June 4, 2018); '430 ADS (May 8, 2018).

support for the limitations claimed in the ’225 Patent, the ’430 Patent, and the ’517 Patent beginning with the earliest application in the family, the Provisional Application, and moving forward chronologically to the ’430 Patent and the ’517 Patent.

1. Priority of the limitations claimed in the ’225 Patent, the ’430 Patent, and the ’517 Patent

293. The ’225 Patent, the ’430 Patent, and the ’517 Patent share substantially identical claim limitations directed to adding certain bromine-containing species to coal before the coal enters the combustion chamber. Due to the substantial similarity of the relevant claim limitations, I have addressed the priority of the three patents together below.

294. During my review, I specifically looked for any disclosure of the following limitations in each of the issued claims of the ’225 Patent, the ’430 Patent, and the ’517 Patent:

- “the coal comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber” (claims 1, 28, and 29 of the ’430 Patent)

- “the coal comprising an additive comprising Br_2, HBr, a bromide compound, or a combination thereof” (claim 1 of the ’517 Patent)

- “the coal comprises added Br_2, HBr, bromide compound, or a combination thereof, added to the coal before the coal

enters the combustion chamber" (claims 29 and 30 of the '517 Patent).

- "combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas" (claims 1, 14, and 17 of the '225 Patent)

- "the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber" (claim 20 of the '225 Patent)

295. As I explain below, I have determined that neither the Provisional nor any of the intervening applications filed between the Provisional and the '558 Application—the application that led to the '225 Patent—include any disclosure of the above-referenced claim limitations. In fact, the only disclosure of adding certain bromine-containing species to the coal before the coal enters the combustion chamber in the '225 Patent is found in the language of the claims themselves.

296. Similarly, I have determined that there is no disclosure of the above-referenced claim limitations in any of the applications filed between the '558 Application and the '970 Application—the application prior to the '430 Patent. Therefore, I have determined that there is no disclosure of the above-referenced claim limitations prior to April 12, 2018. Finally, I have determined that there is an insufficient description of the addition of bromine-containing species to coal prior

to combustion in the ’970 Application and the ’430 and ’517 Patents to support such limitations in the claims.

2. The Provisional Does Not Support the Relevant Claim Limitations of the ’225 Patent, the ’430 Patent, and the ’517 Patent

297. A person of ordinary skill in the art would not consider the technical disclosures in the Provisional to disclose the aforementioned limitations in the issued claims of the ’225 Patent, the ’430 Patent, and the ’517 Patent.

298. ME2C has cited Figure 2 of the Provisional and its accompanying description in support of the claim limitations directed to certain bromine-containing species being added to the coal before entering the combustion chamber. However, this disclosure does not fully support the relevant claims. Figure 2 of the Provisional is reproduced below:[466]

[466] Ex. 1020 (Provisional) at exhibit page 16 (Fig. 2).

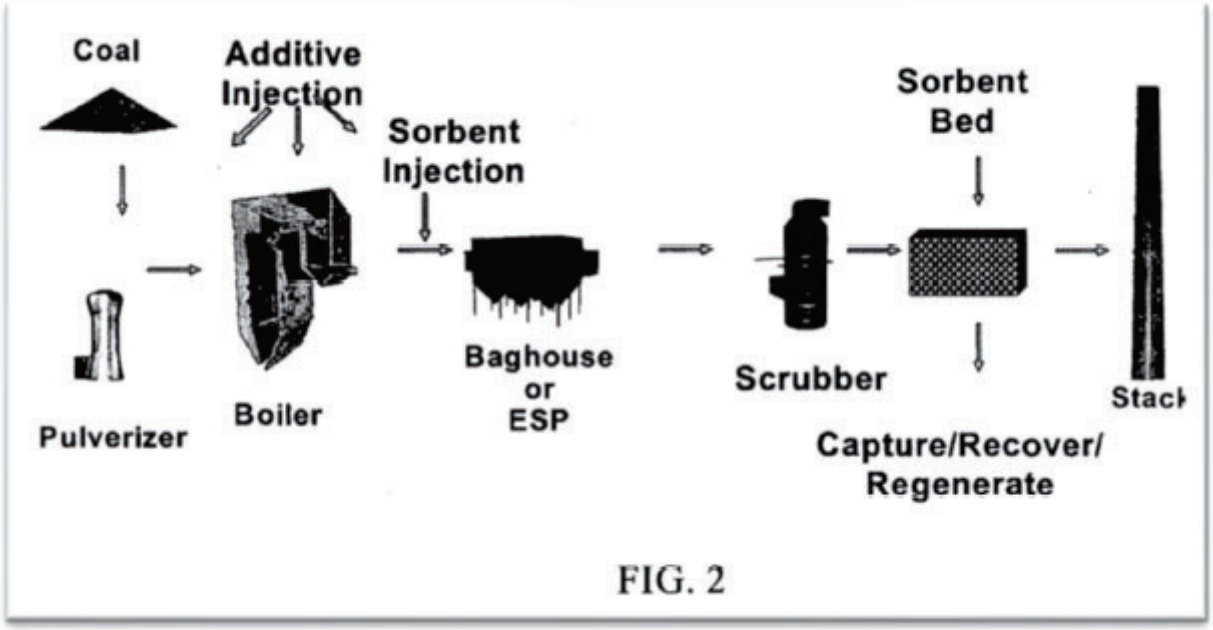


FIG. 2

299. Figure 2 of the Provisional includes a label with "Additive Injection" having three arrows generically in the direction of the boiler of a coal-fired power plant. The accompanying written description provides the only context of what is illustrated by this figure:[467]

DESCRIPTION OF EXEMPLARY EMBODIMENTS

FIG. 2 is a block diagram illustrating the use of the invention in a coal fueled facility. Of course, the invention can also be used in any other desired type of facility. FIG. 2 shows a boiler for burning pulverized coal. The facility utilizes various devices to clean the exhaust of the boiler. In this example, a baghouse or ESP is used to collect particulates in the exhaust. A scrubber and sorbent bed are also used to remove undesired constituents from the flue gas stream, before being fed to the stack. In the example shown, the sorbent is injected into the flue gas after the boiler. The additive can be injected where desired (e.g., before, after, or within the boiler).

[467] Ex. 1020 (Provisional) at exhibit page 15 (emphasis added).

300. As discussed above with respect to the '114 Patent, where the Provisional refers to the additive, it describes "additives of base chemistry" that are "comprised of Group I or Group II elements, such as Ca, Na, and others."[468] These additives are explained in more detail by "outline of examples of the invention" number 9, reproduced below as annotated:[469]

> 9. The process of using additives (1-8) in conjunction with sorbents to capture acid gases and other flue gas constituents that block oxidation reactions or consume sorbent sites that would otherwise capture mercury. The additive is a compound comprised of Group I or II elements, such as Ca, Na, and others. These additives of base chemistry may be added to flue gas as a sorbent mixture or co-injected to selectively sorb acid gases or other gas constituents that compete for mercury reactive/sorption sites, thereby improving the effectiveness of activated carbon to capture mercury. In addition, the base additives can augment the treated activated carbon by helping to capture oxidized mercury forms in the flue gas, such as mercuric chloride, or that are produced on the carbon sorbent, such as mercuric bromide, but are released to the gas phase as the sorbent becomes saturated or capacity limited.

Halogens (including bromine) are in Group VII, and not Groups I or II. This makes clear that the "additive" disclosed by the Provisional is not the bromine-containing promoter itself but is instead a non-bromine based additive of base chemistry of Ca (Calcium), Na (Sodium), or other alkali—those elements in the first two groups (columns) of the periodic table. The primary function recognized by this alkali additive is to neutralize other contaminants within the flue gas that would otherwise "compete for mercury reactive/sorption sites."[470]

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468 Ex. 1020 (Provisional) at exhibit page 4 (Abstract).
469 Ex. 1020 (Provisional) at exhibit page 7
470 Ex. 1020 (Provisional) at exhibit page 7

301. And, even assuming for the sake of argument, that the words, "the additive can be injected," were to refer to injecting a bromine-containing promoter—as opposed to injecting an alkali component used to capture "acid gases or other [flue] gas constituents"[471]—Figure 2 of the Provisional does not support adding the additive "to the coal" before combustion. A POSITA would not necessarily understand that injecting an additive "before . . . the boiler" involves adding the promoter to the coal, as there are a number of systems ahead of the boiler that do not interface with coal—including secondary-air systems and/or low-NOx overfire air systems.[472] Injecting an additive "before . . . the boiler" could also involve a specialized additive injection system leading to the boiler, that does not interact with the coal before being introduced to the combustion chamber. Certainly, it is not express or inherent from Figure 2 or its description that the additive is added to the coal prior to combustion.

302. Accordingly, the Provisional fails to clearly disclose that ***the coal*** comprises added bromine-containing species prior to combustion, as required by each of the relevant claims of the '225 Patent, the '430 Patent, and the '517 Patent.

3. The '163 Application and the Intervening Applications Do Not Support the Claim Limitations of the '225 Patent, the '430 Patent, and the '517 Patent

[471] Ex. 1020 (Provisional) at p.7 (item 9: "additives of base chemistry").
[472] Ex. 1027 (B&W: Steam) at 13-3

303. I have also reviewed the ’163 Application, as originally filed August 22, 2008, as well as the linear chain of continuation applications filed up to the ’558 Application. Nothing in the text or figures of the ’163 Application or any of the intervening applications discloses the aforementioned, relevant claim limitations. While, as previously discussed, Figure 2 of the Provisional and its description do not support the limitation of adding bromine-containing species to the coal before combustion, it is also notable that they are entirely absent from each of the linear chain of continuation applications filed up to the ’558 Application. While these applications do include a generic statement of incorporation of the Provisional by reference, I am informed that, as a legal matter, this is insufficient to permit consideration of that material for a priority analysis.

304. Further, none of these applications contain any additional disclosures adding a bromine-containing species to the coal recited in the ’225, ’430, and ’517 Patent claims. This is not surprising considering the ’163 Application and the later filed applications in the priority chain, even including the ’430 and ’517 Patents, discuss preparing a brominated activated carbon outside of the mercury-containing flue gas, and then injecting the brominated sorbent into the mercury-containing flue gas downstream from the combustion chamber. Nothing in the ’163 Application or any of the intervening applications describes adding the bromine promoter independently from the mercury sorbent, let alone to the coal.

4. The ’558 Application Does Not Support the Relevant Claim Limitations of the ’225 Patent or of the ’430 Patent and the ’517 Patent

305. The ‘225 patent claims “[a] method for treating a mercury-containing gas, the method comprising: combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas . . .” and an embodiment where the “HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber.” (claims 1, 14, 17, and 20 of the ’225 Patent).

306. The basis for ME2C’s assertion to the Examiner during prosecution that there was sufficient written description to support its final claims—with regard to the addition of bromine-containing additives to coal before combustion—was paragraph [0119] of the published ’558 application (now the ‘225 Patent).[473] Paragraph [0119] states, “[i]n general however, the inventive *sorbent* can be injected where desired (e.g., before, after, or within the boiler).”[474] With regard to the claim that “the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal

[473] ‘225 Applicant Argument/Remarks Made in an Amendment at 1 (June 13, 2018).
[474] 14/712,558 at 11 (Published Sept. 3, 2015) (emphasis added).

before the coal enters the combustion chamber," paragraph [0119] was the entire basis for the written description of the claim.[475]

307. The language contained in paragraph [0119]—which was also in the preceding applications—cannot support the claim limitations in the '225 Patent. In particular, that language requires the sorbent to be injected before combustion. However, it does not describe the addition of bromine-containing additives to coal before combustion independent of the addition of the sorbent.

308. Further, as previously discussed, there is no support for the relevant claim limitations in the prior applications in the family. Therefore, the relevant claim limitations of the '225 Patent lack support.

5. The Passages Cited by ME2C During Prosecution of the '430 Patent and the '517 Patent Do Not Support the Claim Limitations of the '430 Patent and the '517 Patent

309. During prosecution of the '430 Patent and the '517 Patent, ME2C amended the independent claims to recite certain bromine-containing species being added to the coal before entering the combustion chamber. In support of these amendments, ME2C cited paragraphs [0042], [0054], [0072], [0077]-[0086], and Figure 11 of the published applications of the '430 Patent and the '517 Patent. I note that the content of paragraphs [0042], [0054], [0072], [0077]-[0086], and Figure 11

[475] *See* '225 Applicant Argument/Remarks Made in an Amendment at 1 (July 10, 2018).

in each of the published applications of the ’430 Patent and the ’517 Patent is identical. I further note that Figure 11 and the accompanying description are Figure 2 and the accompanying description from the Provisional. They were added back into the patent family in the ’970 Application.

310. I reviewed each of the above-cited portions of the ’430 Patent and the ’517 Patent cited by ME2C in support of the claim limitations directed to certain bromine-containing species being added to the coal before entering the combustion chamber. I note that Figure 11 is the only disclosure cited by ME2C that originates from the Provisional.

311. None of the paragraphs identified by ME2C from the published applications of the ’430 and ’517 Patents as supporting the independent claims clearly disclose that the coal comprises added bromine-containing species, as required by each of the independent claims of the ’430 Patent and the ’517 Patent. Paragraphs [0042], [0054], and [0072] of the published applications of the ’430 Patent and the ’517 Patent simply describe the characteristics of a promoted sorbent and a mechanism for how it reacts with mercury, but do not describe any bromine-containing species being added to the coal. Paragraphs [0077]-[0086] of the published applications of the ’430 Patent and the ’517 Patent merely refer to a

halogen promoter being contacted with a base sorbent in a flue gas, but again do not refer to any bromine-containing species being added to the coal.[476]

XV. CLAIM CONSTRUCTION

312. I have reviewed how a POSITA would have understood terms in the Challenged Claims. I have reviewed the Court's Claim Construction ruling in this case and have applied the meanings in that ruling in conducting my analysis below. Apart from those terms, I did not apply any special meaning to any of the claim terms.

XVI. OVERVIEW OF THE PRIOR ART

I. THE NELSON REFERENCE

313. Ex. 1012 ("Nelson") is U.S. Patent No. 6,953,494, which names Sidney G. Nelson Jr. as the sole inventor. Nelson is entitled, "Sorbents and Methods for the Removal of Mercury from Combustion Gases."

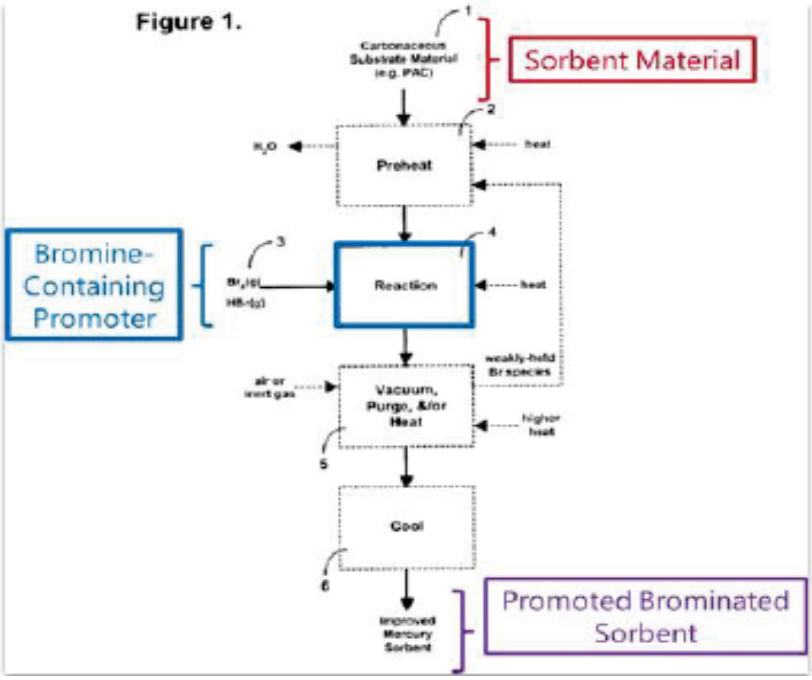
1. Prior-Art Status of the Nelson Reference

314. Nelson was issued by the USPTO on October 11, 2005 from U.S. Patent Application No. 10/430,577, which was filed May 6, 2003. Nelson traces ultimate priority to U.S. Patent Provisional No. 60/377,790, which was filed on May 6, 2002. Accordingly, I understand that Nelson qualifies as prior art at least as of May 6, 2003.

[476] Ex. 1026 ('114 Patent File History) at 33.

2. Overview of the Disclosure of Nelson

315. Nelson describes remediating "the mercury emitted from coal-fired power plants."[477] Nelson provides a sorbent in the form of powdered activated carbon (PAC), reacts the PAC with bromine-containing gases and, as a result, the "brominated PAC achieved 90% mercury removal."[478] Figure 1 of Nelson, reproduced below, is annotated to emphasize the preparation of promoted sorbent (purple) by chemically reacting powdered-activated carbon (PAC) sorbent (red) with HBr and/or Br_2 promoter (blue): [479]



316. Nelson recognizes that he was not the first to remove mercury from flue gas using halogens and activated carbon. Nelson acknowledges that "many mercury

[477] Ex. 1012 (Nelson) at 1:53-54.
[478] Ex. 1012 (Nelson) at 14:12-14.
[479] Ex. 1012 (Nelson) at Figure 1 (annotated).

control techniques have already developed," and provides a solution "for effectively and economically controlling utility mercury emissions" from flue gas.[480] Nelson describes that the state of the prior art had already demonstrated the ability to remove mercury with activated carbon: "In the past, activated carbons have demonstrated utility for sequestering mercury vapor in some applications."[481] Nelson also recognized that even in his time, it was well-known that the "mercury sequestration performance of activated carbons can be improved" by combining the activated carbon "with halogen compounds."[482] For example, Nelson cites to a patent to Stock, issued in 1934,[483] that "teaches the advantages of loading activated carbon with halogens, for example iodine, to remove mercury from ambient air."[484] The Stock patent states:

> [I]t was found that in the process of purifying air vitiated with mercury vapors, adsorption agents which are impregnated with a halogen will constitute a protective agent, which is incomparably superior to any of the above mentioned protectives. For instance, active carbon impregnated with iodine will surpass the protective action of non-impregnated active carbon about ten times.[485]

317. Nelson recognized that it was well-known that other halogens, besides iodine, could be "advantageously applied to carbon substrates to promote mercury

[480] Ex. 1012 (Nelson) at 1:62-65.
[481] Ex. 1012 (Nelson) at 2:9-10.
[482] Ex. 1012 (Nelson) at 2:10-13.
[483] Ex. 1029 (Stock).
[484] Ex. 1012 (Nelson) at 2:16-20.
[485] Ex. 1029 (Stock) at 1:33-41.

sequestration."[486] Whereas "iodine compounds are primarily or only physically adsorbed by carbonaceous materials" and thus desorb more easily, other halogens, particularly "chlorine and bromine, . . . *chemically react with* strongly-held carbon surface compounds" and thus adsorb more strongly.[487] Accordingly, Nelson seeks a promoter that can chemically react, and form a stronger bond, with activated carbon, and selects chlorine and bromine.

318. Nelson describes that although bromine and chlorine are each advantageous over iodine for purposes of promoting activated carbon, Nelson identifies "particular advantages of using bromine, rather than iodine or iodides, or chlorine or chlorides, with activated carbons for mercury control."[488] Although "[g]aseous bromine and hydrogen bromide have been combined with carbon substrates before," Nelson seeks to use the combination in order "to sequester mercury from hot combustion-gas streams."[489]

319. For the sorbent, Nelson discloses several brands of "commercially-available powdered activated carbons (PACs)." He provides several examples using activated carbon by Norit because "Norit's Darco FGD® is a common PAC frequently used by other researchers as a comparative yardstick."[490]

---

[486] Ex. 1012 (Nelson) at 2:53-56; *see also* Ex. 1012 (Nelson) at 2: 56-3: 9.
[487] Ex. 1012 (Nelson) at 2:36-39 (emphasis added).
[488] Ex. 1012 (Nelson) at 3:44-46.
[489] Ex. 1012 (Nelson) at 3:47-49; *see also* Ex. 1012 (Nelson) at 4: 64-67.
[490] Ex. 1012 (Nelson) at 11:17-19.

320. Nelson promotes the sorbent by exposing the activated carbon to bromine gas, such that "a relatively large quantity of the bromine reacts with the carbon, forming surface compounds on the large-surface area of the carbon."[491] Nelson recognizes that his solution is effective for removing both "elemental mercury and oxidized mercury species" from the flue gas, in that they both "react with at least one form of the bromine-carbon surface compounds that were created and are held fast."[492] Through exposing the PAC "to gaseous bromine, $Br_2(g)$, or to gaseous hydrogen bromide, HBr(g)," Nelson was able to increase the PAC's "ability to remove mercury species when injected into high-temperature coal-fired flue gas compositions."[493]

321. Nelson uses the same reactants at the same concentrations at the same temperature and in the same type of reactor as the '114 Patent, each to produce an improved mercury-sorbent composition.

Component	Nelson	'114 Patent
Promoter[494]	"gaseous bromine, $Br_2(g)$, or to gaseous hydrogen bromide, HBr(g)"	"gaseous HBr or Br_2"
Sorbent[495]	"powdered activated carbons (PACs)"	"powdered activated carbon"
Promoter/Sorbent Ratio"[496]	1 wt% — 30 wt%, including 1.5%, 5%, and 15%	1-30 wt% of the carbon, including 15%

[491] Ex. 1012 (Nelson) at 6:27-30.
[492] Ex. 1012 (Nelson) at 6:31-34; *see also* Ex. 1012 (Nelson) at 6:7-10.
[493] Ex. 1012 (Nelson) at 6:11-15.
[494] Ex. 1012 (Nelson) at 6:10-13; Ex. 1001 ('114 Patent) at 15:61-67.
[495] Ex. 1012 (Nelson) at 11:10-19; Ex. 1001 ('114 Patent) at 11:8-11.
[496] Ex. 1012 (Nelson) at 8:37-50, Figure 14; Ex. 1001 ('114 Patent) at 4:39-48, 16:5-11.

Reactor to prepare promoted sorbent[497]	"fluidized-bed unit"	"fluidized bed"

3. Treatment of Nelson During Prosecution of '114 Patent

322. I understand that prior to issuance as a patent, Application No. 10/430,577 was published by the USPTO on January 8, 2004 as U.S. Patent Pub. No. 2004/0003716. U.S. Patent Pub. No. 2004/0003716 (the "Nelson Publication") is provided as Exhibit 1013 to my declaration.

323. The Nelson Publication was discussed by the USPTO examiner during prosecution of the Challenged Patent, as I discuss above in Section IX.C.3. However, the Examiner relied heavily on Felsvang as a primary reference as disclosing almost all of the limitations of the claims, and relied on Nelson as a secondary reference for discrete limitations from certain claims. [498]

> [claim 2]: The Nelson reference discloses the halogen or halide promoter comprising Br_2, HBr, Br—, or a combination thereof to promote activated carbon . . . so as to provide an effective carbon sorbent for mercury.
>
> [claim 5]: The Nelson reference discloses optimizing the amount [of bromine] so as to obtain a desired mercury reactivity. It would have been obvious to one having ordinary skill in the art before the invention was made to have modified [Felsvang] to include the promoted sorbent comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material so as to . . . ensure optimum reaction between

[497] Ex. 1012 (Nelson) at 8:60-62; Ex. 1001 ('114 Patent) at 23:9, 23:30-36, 31:6- 13.
[498] Ex. 1026 ('114 Patent File History) at exhibit pages 1609-13 (10/10/2018 Office Action).

> the halogen and the activated carbon (Nelson paragraph [0054]).
>
> [claim 18]: The Nelson reference discloses the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber (figure 4, objects 71, 64 and 22 and paragraph [0062]). It would have been obvious to one having ordinary skill in the art before the invention was made to have modified the Felsvang et al. reference to include the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separate or a scrubber . . . so the process can be used in a plant which has a "hot-side" ESP and still have effective mercury capture.
>
> [claim 19]: Nelson Felsvang et al. [sic] reference discloses the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separate or a scrubber (figure, objects 4, 12, 14, 1 and 2).

Throughout subsequent prosecution of the '114 Patent, the Examiner noted that "[t]he Nelson reference discloses optimizing the amount [of bromine] so as to obtain a desired mercury reactivity."[499] In particular, the Examiner explained "[i]t would have been obvious to one having ordinary skill in the art before the invention was made to have modified [prior art] to include the promoted sorbent comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material so as to . . . ensure optimum reaction between the halogen and the activated carbon."[500]

[499] Ex. 1026 ('114 Patent File History) at exhibit page 1611 (10/10/2018 Office Action).
[500] Ex. 1026 ('114 Patent File History) at exhibit page 1611 (10/10/2018 Office Action).

J. THE VOSTEEN PATENT

324. Ex. 1008 ("Vosteen") is U.S. Patent No. 6,878,358, which names Bernard Vosteen as the lead inventor. Vosteen is entitled, "Process for Removing Mercury from Flue Gases."

1. Prior-Art Status of Vosteen

325. Vosteen was originally issued by the USPTO on April 12, 2005 from U.S. Patent Application No. 10/430,088, which was filed May 6, 2003. Vosteen traces priority to U.S. Patent App. No. 10/202,571 (filed on July 24, 2002), which itself traces priority to DE 102 33 173 (filed July 22, 2002). Accordingly, I understand that Vosteen qualifies as prior art at least as of May 6, 2003.

2. Overview of the Disclosure of Vosteen

326. Vosteen describes processes for the "removal of mercury from the flue gases in a flue gas emission control system downstream of the combustion," in plants such as "power stations, for example bituminous coal-fired or lignite-fired power stations."[501] Vosteen describes removing mercury by feeding "bromine and/or a bromine compound and/or a mixture of various bromine compounds" into the "multistage furnace and/or to the flue gas."[502] Vosteen further introduces a sulphur compound with the bromine-containing promoter in order to maximize the concentration of Br_2 at the expense of Cl_2.

[501] Ex. 1008 (Vosteen) at 2:16-20, 235-37.
[502] Ex. 1008 (Vosteen) at 2:2-4.

327. Vosteen discussed that although mercury removal with chlorine and iodine compounds was well-known, "it has been found that bromine compounds oxidize mercury more effectively under the given conditions of high-temperature processes."[503] Vosteen included activated carbon (a type of "dry sorbent") as part of the mercury removal process, and found: "Mercury bromide $HgBr_2$ adsorbs more strongly to dry sorbents than mercury chloride $HgCl_2$."[504] As a result, Vosteen discloses the ability to remove more than 90% of mercury.[505]

K. THE DOWNS-BOILER REFERENCE

328. Ex. 1006 ("Downs-Boiler") is U.S. Patent Application Publication No. 2008/0107579, which names William Downs and George Albert Farthing as co-inventors and was assigned to The Babcock & Wilcox Company. Downs-Boiler is entitled "Bromine Addition for the Improved Removal of Mercury from Flue Gas." Downs-Boiler was not applied in any rejecting to the claims during prosecution of the '114 Patent.

1. Prior-Art Status of the Downs-Boiler Reference

329. I have been informed that Downs-Boiler was published by the USPTO on May 8, 2008 as U.S. Patent Pub. No. 2008/0107579 from U.S. Patent Application No. 10/591,855—a U.S. application nationalized on September 5, 2006. I have been

[503] Ex. 1008 (Vosteen) at 4:47-50.
[504] Ex. 1008 (Vosteen) at 5:19-39.
[505] Ex. 1008 (Vosteen) at Figure 5.

further informed that App. No. 10/591,855 traces priority to a Patent Cooperation Treaty international application—PCT/US05/09590 filed on March 21, 2005. I have been informed that Downs-Boiler traces ultimate priority to a U.S. Provisional Patent Application No. 60/555,353 ("Downs-Boiler-Provisional"),[506] which was filed on March 22, 2004.

330. I understand that Downs-Boiler qualifies as prior art at least as of its filing date of March 21, 2005. I further understand that, to the extent that the claims and disclosure of Downs-Boiler have written-description support from Downs-Boiler-Provisional, that Downs-Boiler qualifies as prior art as of the March 22, 2004 filing date of Downs-Boiler-Provisional. Accordingly, I have been asked to evaluate Downs-Boiler to determine whether or not: (a) claim 1 in Downs-Boiler has written-description support in Downs-Boiler-Provisional; and also whether (b) the disclosures that I rely on, in comparing Downs-Boiler to the Challenged Claims, have written-description support in Downs-Boiler-Provisional. For the first inquiry, I have prepared a claim chart in the subsections below that compares claim 1 of Downs-Boiler to the disclosures in Downs-Boiler-Provisional. For the second inquiry, I have included parallel cites to both Downs-Boiler and to Downs-Boiler-Provisional for materials I rely on.

2. Overview of the Disclosure of Downs-Boiler

[506] Ex. 1007 (Downs-Boiler-Provisional).

331. Downs-Boiler describes processes for improving the removal of mercury released from the combustion of coals. Downs-Boiler discloses that the "mercury removal" may be performed with "carbonaceous sorbents [that] include, but are not limited to, powdered activated carbon (PAC)."[507] Downs-Boiler seeks to enhance the effectiveness of mercury removal, including through PAC, by using a bromine-containing promoter added either to the coal or to a combustion furnace.[508] Downs-Boiler describes various example points of application A, B, and C for introducing bromine to the boiler as illustrated in Figure 2, reproduced below as annotated: [509]

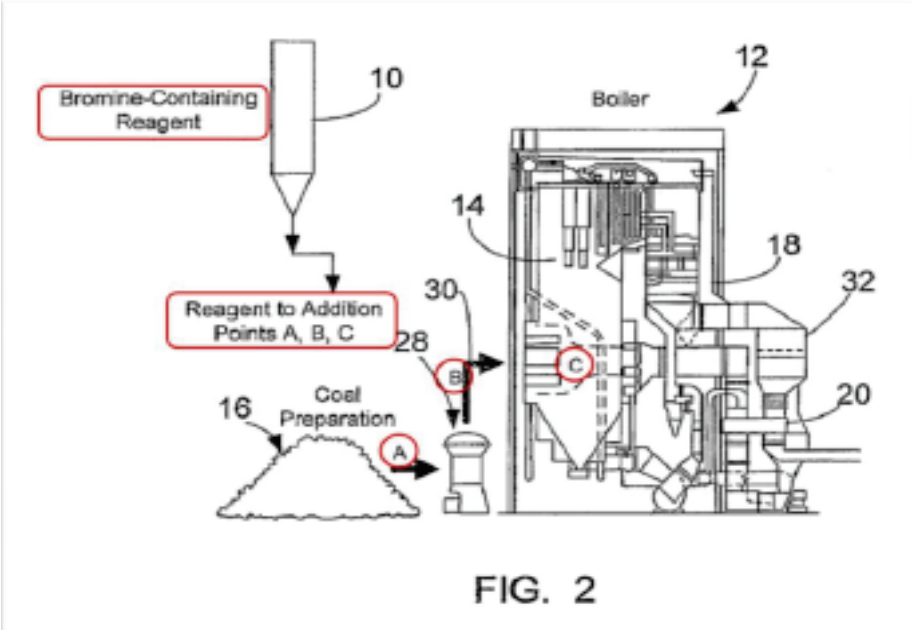


FIG. 2

332. Downs-Boiler further explains:

[507] Ex. 1006 (Downs-Boiler) ¶ [0025].
[508] Ex. 1006 (Downs-Boiler) at Abstract.
[509] Ex. 1006 (Downs-Boiler) at Figure 2; *see also* Ex. 1007 (Downs-Boiler-Provisional) at Figure 2.

> A bromine-containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16. Bromine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace 14 and, in particular, through the cooler sections of the boiler convection pass 18 and combustion air preheater 20. The increased fraction of mercury appearing in the oxidized form enhances mercury removal in downstream pollution control systems such as wet 22 and SDA 24 FGD systems, and PAC injection systems.[510]

Downs-Boiler describes that the bromine-containing reagent can be fed in either "gaseous, liquid, or solid form."[511] The reagent could be made from "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)."[512] Examples of alkali earth metal bromides include calcium bromide ($CaBr_2$).[513]

3. Comparison of Downs-Boiler to Provisional Application

333. Exhibit 2013 ("Downs-Boiler-Redline") is a redline comparison between U.S. Patent Pub. No. 2008/0107579 (Downs-Boiler) and U.S. Provisional Application No. 60/555,353 (Downs-Boiler-Provisional), using Downs-Boiler-Provisional as the original version.[514] As illustrated by the minor substantive changes shown in Downs-Boiler-Redline, all of the subject matter relied upon in Downs-Boiler is supported in Downs-Boiler-Provisional. Accordingly, when I discuss the Downs-Boiler reference in my declaration, I include parallel citations to

[510] Ex. 1006 (Downs-Boiler) ¶ [0015]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018].
[511] Ex. 1006 (Downs-Boiler) ¶ [0022].
[512] Ex. 1006 (Downs-Boiler) ¶ [0021].
[513] Ex. 1006 (Downs-Boiler) ¶¶ [0018], [0021].
[514] Ex. 1032 (Downs-Boiler-Redline).

Downs-Boiler-Provisional. All of the subject matter I rely on in Downs-Boiler is supported in Downs-Boiler-Provisional.

334. I have also compared Claim 1 of Downs-Boiler with the disclosure in Downs-Boiler-Provisional and determined that Downs-Boiler-Provisional provides written-description support for at least Claim 1 of Downs-Boiler. My analysis is summarized in the paragraphs below.

a. **Element 1(a): "A method of removing a portion of the elemental mercury in a flue gas created during the combustion of a fossil fuel, comprising: "**

335. Downs-Boiler-Provisional discloses this preamble. The title of the disclosure is "Bromine Addition for the *Improved Removal of Mercury from Flue Gas* ."[515] Downs-Boiler-Provisional further discloses that the "invention promises to significantly reduce the cost of mercury removal at coal-fired electric plants."[516] Downs-Boiler-Provisional discloses that it removes both oxidized mercury and elemental mercury from mercury-containing flue gases.[517] For example, Downs-Boiler-Provisional discusses that "the current invention can offer a cost-effective method of removing elemental mercury from coal combustion flue gases."[518]

b. **Element 1(b): "providing a bromine containing reagent to said flue gas;"**

---

[515] Ex. 1007 (Downs-Boiler-Provisional) at Title (emphasis added); see also Ex. 1007 (Downs-Boiler-Provisional) at Claim 1 ("1. *A method of reducing the mercury concentration of a flue gas* comprising; adding a bromine containing agent to the combustion chamber.") (emphasis added); Ex. 1006 (Downs-Boiler) at Title.
[516] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019]; *see also* Ex. 1006 (Downs- Boiler) ¶ [0016].
[517] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0002]—[0006], [0019], [0027].
[518] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0021].

336. Downs-Boiler-Provisional discloses this element. Again, the title of the disclosure is "*Bromine Addition* for the Improved Removal of Mercury from *Flue Gas*."[519] Downs-Boiler-Provisional further describes the ability "to promote the oxidation of elemental mercury if the correct species (in this case bromine species) are present in the flue gases."[520]

337. With reference to annotated Figure 2, annotated below, Downs-Boiler-Provisional first describes adding a "bromine-containing reagent" "to the boiler combustion furnace."[521]

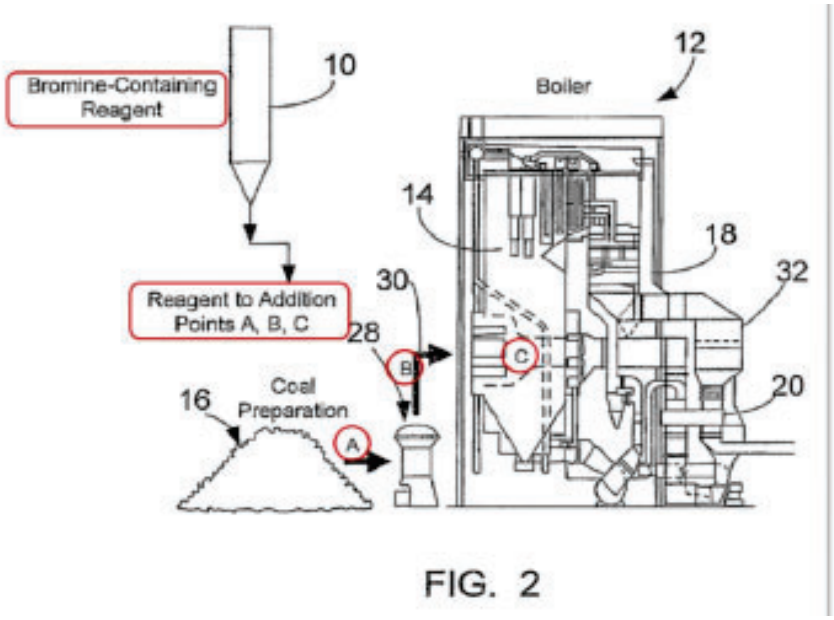


FIG. 2

338. Downs-Boiler-Provisional goes on to explain that a purpose of adding this bromine-containing reagent is ultimately to provide the bromine-containing

[519] Ex. 1007 (Downs-Boiler-Provisional) at Title (emphasis added); see also Ex. 1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the *mercury concentration of a flue gas comprising; adding a bromine containing agent to the combustion chamber.*") (emphasis added); Ex. 1006 (Downs-Boiler) at Title.
[520] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0027]; Ex. 1006 (Downs-Boiler) ¶ [0024].
[521] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018]; *see also* Ex. 1006 (Downs-Boiler) ¶ [0015].

reagent to the flue gas. "Bromine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace," travel downstream (*i.e.*, to the flue gas region of the power plant), and the bromine then "enhances mercury removal in downstream pollution control systems such as wet and SDA FGD systems, and PAC injection systems."[522]

c. Element 1(c): "promoting the oxidation of elemental mercury with the bromine containing reagent: "

339. Downs-Boiler-Provisional discloses this limitation. In describing the two primary benefits realized by employing the bromine-containing reagent, Downs-Boiler-Provisional discloses:

> The removal of *elemental mercury* from coal combustion gases generated by electric utility plants through the application of a conventional PAC injection process is very expensive. The current invention promises to significantly reduce the cost of mercury removal at coal-fired electric plants in two ways. First, *increasing the fraction of mercury appearing in the oxidized and particulate-bound forms enhances the removal of mercury* in conventional pollution control systems such as particulate collectors and wet and SDA FGD systems. This reduces, or may eliminate entirely, the need for PAC injection to *remove elemental mercury.* Second*, the increased fraction of oxidized mercury* also enhances the removal of mercury across a PAC injection process, due to the higher reactivity of oxidized mercury with PAC.[523]

[522] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018]; *see also* Ex. 1006 (Downs-Boiler) ¶ [0015].
[523] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019] (emphasis added); *see also* Ex. 1006 (Downs-Boiler) ¶ [0016].

340. Downs-Boiler-Provisional makes clear that the effect of the bromine-containing reagent is a promotion of the oxidation of elemental mercury, describing that power plants with a selective catalytic reduction (SCR) system "have been shown to *promote the oxidation of elemental mercury* if the correct species (in this case bromine species) are present in the flue gases."[524]

d. Element 1(d): "creating an oxidized form of mercury from the elemental mercury; and"

341. Downs-Boiler-Provisional discloses this claim element. Downs-Boiler-Provisional explains that vapor-phase mercury from the combustion of coal come in two forms, "as elemental mercury (elemental, metallic mercury vapor) or as oxidized mercury (vapor-phase species of various compounds of mercury). Speciation, the form of mercury present, is a key factor in the development of mercury emissions control strategies."[525]

342. As described above with respect to Claim Element 1(c) of Downs-Boiler, Downs-Boiler-Provisional teaches converting the elemental mercury to its oxidized form, thereby increasing the fraction of oxidized mercury in the flue gas (as compared to elemental mercury).[526] Thus, Downs-Broiler-Provision teaches to create oxidized forms of mercury from the elemental mercury by oxidizing the

[524] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0027] (emphasis added); *see also* Ex. 1006 (Downs-Boiler) ¶ [0024].
[525] Ex. 1007 (Downs-Boiler-Provisional) ¶ [003]; see also Ex. 1006 (Downs-Boiler) ¶ [0002].
[526] Ex. 1007 (Downs-Boiler-Provisional) ¶ [003]; see also Ex. 1006 (Downs-Boiler) ¶ [0002].

available elemental mercury.[527] As explained by Downs-Boiler-Provisional, this is achieved by adding the bromine-containing reagent to the boiler such that "[b]romine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace" which is inexorably from the "removal of [the] elemental mercury from [the] coal combustion gases."[528]

e. Element 1(e): "removing the oxidized mercury from the flue gas."

343. Downs-Boiler-Provisional provisional discloses this claim element. Once more, the title of the disclosure is "Bromine Addition for the Improved *Removal of Mercury from Flue Gas*."[529]

344. Downs-Boiler-Provisional explicitly acknowledges that it is known in the art that mercury—especially mercury appearing in its oxidized form—is readily removed from the flue gas by conventional pollution control systems, such as "PAC injection [which] removes both oxidized and elemental mercury species, although removal efficiencies are higher for the oxidized form."[530] Downs-Boiler-Provisional further states, for example, that "the *increased fraction of oxidized mercury also enhances the removal of mercury across a PAC injection process, due to the higher*

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[527] Ex. 1007 (Downs-Boiler-Provisional) ¶¶ [0018-19]; see also Ex. 1006 (Downs-Boiler) ¶ [0015-16].
[528] Ex. 1007 (Downs-Boiler-Provisional) ¶¶ [0018-19]; see also Ex. 1006 (Downs-Boiler) ¶ [0015-16].
[529] Ex. 1007 (Downs-Boiler-Provisional) at Title (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the *mercury concentration of a flue gas comprising*; *adding a bromine containing agent to the combustion chamber.")* (emphasis added); Ex. 1006 (Downs-Boiler) at Title.
[530] Ex. 1007 (Downs-Boiler-Provisional) ¶ [005]; see also Ex. 1006 (Downs-Boiler) ¶ [0004].

reactivity of oxidized mercury with PAC."[531] The mercury-sorbent composition can be removed with "electrostatic precipitators (ESP) or fabric filters (FF), sometimes called baghouses," as well as in "wet and spray dryer absorber (SDA) flue gas desulfurization (FGD) systems. "[532]

A. THE DOWNS-HALOGENATION REFERENCE

345. Ex. 1015 ("Downs-Halogenation") is U.S. Patent Application Publication No. 2007/0180990, which names William Downs and George Farthing Jr. as co-inventors and was assigned to The Babcock & Wilcox Company. Downs-Halogenation is entitled "Dynamic Halogenation of Sorbents for the Removal of Mercury from Flue Gases." Downs-Halogenation was not cited during prosecution of the '147 Patent.

1. Prior-Art Status of the Downs-Halogenation Reference

346. I have been informed that Downs-Halogenation was published by the USPTO on August 9, 2007 as U.S. Patent Pub. No. 2007/0180990 from U.S. Patent Application No. 10/591,856—a U.S. application nationalized on September 5, 2006. I have been further informed that App. No. 10/591,856 traces priority to a Patent Cooperation Treaty international application—PCT/US05/09441 filed on March 21, 2005. I have been informed that Downs-Halogenation traces ultimate

[531] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019]; see also Ex. 1006 (Downs-Boiler) ¶ [0016].
[532] Ex. 1007 (Downs-Boiler-Provisional) ¶ [0004]; see also Ex. 1006 (Downs-Boiler) ¶ [0003].

priority to a U.S. Provisional Patent Application No. 60/555,281 ("Downs-Halogenation-Provisional")[533],' which was itself filed on March 22, 2004.

347. I understand that Downs-Halogenation qualifies as prior art at least as of its non-provisional filing date of March 21, 2005. I further understand that, to the extent that the claims and disclosure of Downs-Halogenation have written-description support from Downs-Halogenation-Provisional, that Downs-Halogenation qualifies as prior art as of the March 22, 2004 filing date of Downs-Halogenation-Provisional. Accordingly, I have been asked to evaluate Downs-Halogenation to determine whether or not: (a) claim 1 in Downs-Halogenation has written-description support in Downs-Halogenation-Provisional; and also whether (b) the disclosures that I rely on, in comparing Downs-Halogenation to the Challenged Claims, have written-description support in Downs-Halogenation-Provisional. For the first inquiry, I have prepared a claim chart in the subsections below that compares claim 1 of Downs-Halogenation to the disclosures in Downs-Halogenation-Provisional. For the second inquiry, I have included parallel cites to both Downs-Halogenation and to Downs-Halogenation-Provisional for those materials I rely on.

2. Overview of the Disclosure of Downs-Halogenation

[533] Ex. 1016 (Downs-Halogenation-Provisional).

348. Downs-Halogenation describes processes for promoting a powdered activated carbon (PAC) sorbent with a bromine-containing compound in order to improve the ability of the PAC to capture mercury released from the combustion of coals.

349. Downs-Halogenation describes a "process for treating sorbents for the removal of mercury from flue gases."[534] Downs-Halogenation mixes "a halogen-containing reagent or compound 24, which may be in gaseous form" with the PAC sorbent.[535] Particularly, the halogen-containing reagents employed by Downs-Halogenation are preferably "bromine-containing compounds" to enhance the capture of elemental mercury by carbonaceous sorbents[536]. Thus, Downs-Halogenation is able to "achieve 90% control of mercury" according to the "cost-effective method" taught by the disclosed process[537].'

350. According to Downs-Halogenation, the disclosed process "maximizes the benefit and utilization of the halogen-containing reagent 24 by placing it exactly where it is needed to facilitate elemental mercury removal—on the surface of the sorbent 14. The sorbent 14 particles with their loading of adsorbed halogen-containing reagent 24 enter the flue gas flue(s) injection locations 28 with high reactivity for removal of elemental mercury.[538] Figure 2 of Downs-Halogenation,

[534] Ex. 1015 (Downs-Halogenation) at ¶ [0019]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0022].
[535] Ex. 1015 (Downs-Halogenation) at ¶ [0019]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0022].
[536] Ex. 1015 (Downs-Halogenation) at ¶ [0010]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0012].
[537] Ex. 1015 (Downs-Halogenation) at ¶ [0023]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026].
[538] Ex. 1015 (Downs-Halogenation) at ¶ [0019]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0022].

reproduced below, illustrates the various elements referred to in the preceding quoted passage.[539]

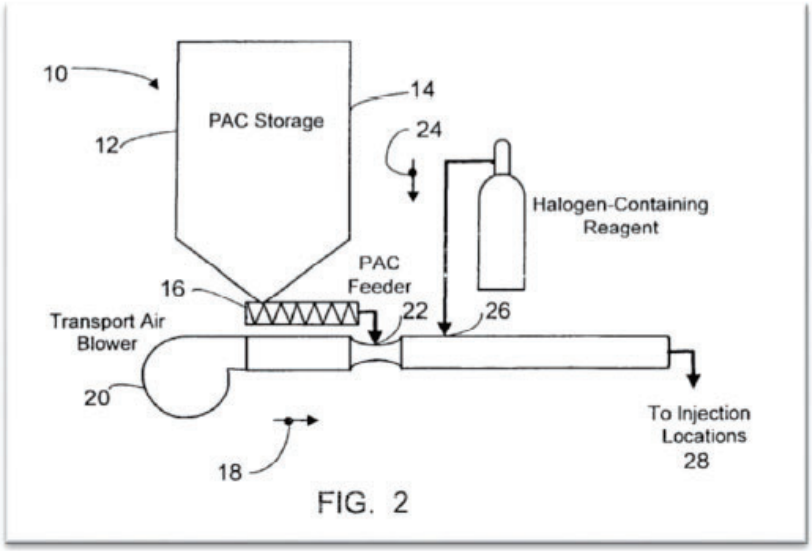


FIG. 2

351. Figures 4-6 of Downs-Halogenation illustrate various non-exclusive configurations of flue-gas emissions control devices where the disclosed mercury removal process may be employed. Representative Figure 5, reproduced below as annotated, illustrates potential injection points for the combined bromine-sorbent substance.[540] In general, the injection points 28 may be "downstream (with respect to a direction of flue gas flow through the installation) of the air heaters" *(i.e.,* air preheaters) and "upstream of the particulate collector devices." *(i.e.,* particulate separation device).[541]

[539] Ex. 1015 (Downs-Halogenation) at Fig. 2; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at Fig. 2.
[540] Ex. 1015 (Downs-Halogenation) at Fig. 5 (annotated); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at Fig. 5.
[541] Ex. 1015 (Downs-Halogenation) at ¶ [0031], Fig. 5 (annotated); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026].

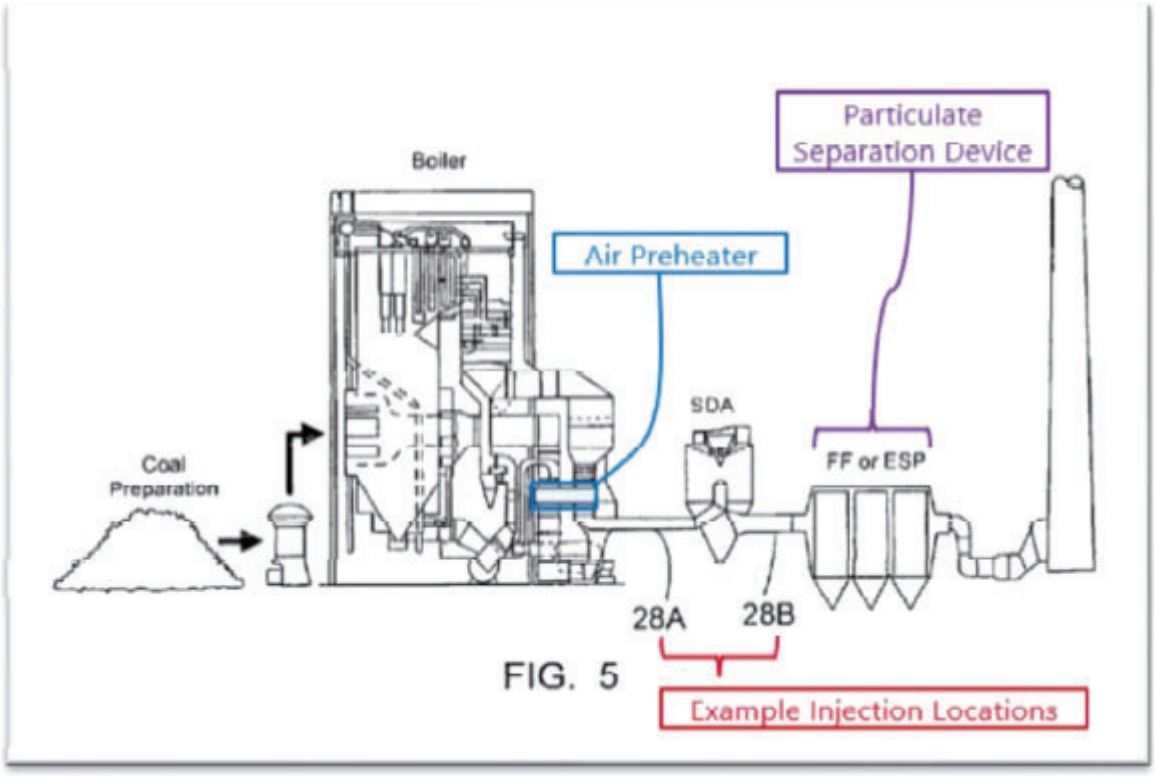


FIG. 5

352. Downs-Halogenation recognizes that this was not the first ever technique for the removal of the various species of mercury resultant from the combustion of coal in utility applications. Downs-Halogenation states that "[n]umerous studies have been, and continue to be, conducted to develop cost-effective approaches to the control of elemental mercury. Many of the studies have focused on the injection of a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas upstream of the particulate collector to adsorb vapor-phase mercury. The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector.[542]"

[542] Ex. 1015 (Downs-Halogenation) at ¶ [0004]; Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [005].

353. In particular, Downs-Halogenation acknowledges that Felsvang[543] had already recognized the use of a halogen "to improve the mercury removal performance of PAC."[544]As characterized by Downs-Halogenation, the concept preferred by Felsvang was that improved mercury removal could be accomplished by "increasing the chlorine-containing species (e.g., hydrogen chloride) in the flue gases … through the addition of a chlorine-containing agent to the combustion zone of the boiler, or through the injection of hydrochloric acid (HCl) vapor into the flue gases.[545]"

354. However, Downs-Halogenation realized improvements over Felsvang by recognizing that the halogen should be placed "onto the sorbent and thereby enhancing the performance of the injected PAC. By making efficient use of the halogen-containing reagent 24, the present invention permits much lower addition rates for the halogen-containing reagent 24 relative to other methods for halogen addition." [546]These improvements included the conclusion that: "1) PAC injection, alone, at a similar injection rate provided no discernable mercury removal; 2) the use of hydrogen bromide was more effective than the use of hydrogen chloride; and 3) the rates of addition of both the hydrogen bromide and

543 Ex. 1007 (Felsvang).
544 Ex. 1015 (Downs-Halogenation) at ¶ [0008]; Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [009].
545 Ex. 1015 (Downs-Halogenation) at ¶ [0008]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [009].
546 Ex. 1015 (Downs-Halogenation) at ¶ [0021]; see also Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0024].

PAC were many times lower than the rates for other halogen addition processes and conventional PAC injection processes, respectively[547].”

3. Comparison of Downs-Halogenation to Provisional Application

355. Exhibit 1018 (“Downs-Halogenation-Redline”) is a redline comparison between U.S. Patent Pub. No. 2007/0180990 (Downs-Halogenation) and U.S. Provisional Application No. 60/555,281 (Downs-Halogenation-Provisional), using Downs-Halogenation-Provisional as the original version.’[548] As illustrated by the minor substantive changes shown in Downs-Halogenation-Redline, all of the subject matter relied upon in Downs-Halogenation is supported in Downs-Halogenation-Provisional. Accordingly, when I discuss the Downs-Halogenation reference in my declaration, I include parallel citations to Downs-Halogenation-Provisional. All of the subject matter I rely on in Downs-Halogenation is supported in Downs-Halogenation-Provisional.

356. I have also compared claim 1 of Downs-Halogenation with the disclosure in Downs-Halogenation-Provisional and determined that Downs-Halogenation-Provisional provides written-description support for at least claim 1 of Downs-Halogenation. My analysis is summarized in the paragraphs below.

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[547] Ex. 1015 (Downs-Halogenation) at ¶ [0023]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026].
[548] Ex. 1018 (Downs-Halogenation-Redline).

a. **Element 1(a): "A method of removing a portion of the elemental mercury in a flue gas created during a combustion process, comprising:"**

357. Downs-Halogenation-Provisional discloses this preamble. The title of the disclosure is "Dynamic Halogenation of Sorbents for the ***Removal of Mercury from Flue Gas***."[549] Downs-Halogenation-Provisional further discloses "the current invention offers a cost-effective ***method of removing elemental mercury from coal combustion flue gases***.[550]

b. **Element 1(b): "providing four streams, wherein the first stream comprises a halogen containing reagent, the second stream comprises a sorbent, the third stream comprises conveyance air, and the fourth stream comprises a flue gas containing elemental mercury:"**

358. Downs-Halogenation-Provisional discloses this element, including four streams: a stream of injected halogen-containing gas *(i.e.*, a first stream), a stream of injected PAC sorbent *(i.e.*, a second stream), a stream of pneumatic transport conveying air, also referred to as "a stream of dynamically-halogenated PAC,"[551] *(i.e.*, a third stream), and stream of elemental-mercury-containing flue gas *(i.e.*, a fourth stream), as provided in the following paragraph:

> The system comprises conventional ***PAC injection system*** comprising a sorbent storage tank, a means for metering the

[549] Ex. 1016 (Downs-Halogenation-Provisional) at Title (emphasis added); *see also* Ex. 1015 (Downs-Halogenation) at Title.

[550] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026] (emphasis added); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at claim 1 ("1. A *method of reducing the mercury concentration of a flue gas* comprising; placing a halogen-containing reagent on a sorbent surface prior to injecting the sorbent surface into the flue gas.") (emphasis added); Ex. 1015 (Downs-Halogenation) at ¶ [0023].

[551] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026]; *see also* Ex. 1015 (Downs-Halogenation) at ¶ [0023].

> sorbent into the sorbent ***transport air stream,*** a sorbent transport air blower supplying the air used to convey the sorbent to the injection locations in the ***flue gas duct(s),*** and a pick-up point where the sorbent is dispersed into the ***transport air stream***. It should be recognized that this is only one embodiment of a ***pneumatic transport conveying system***, and many other configurations could be used or developed by one of ordinary skill in the art without departing from the scope of the current invention. The key aspect of the current invention is that a ***halogen-containing gas is injected*** into the ***flowing transport air/sorbent stream*** at a point close to the point where the sorbent and transport air first mix. This is done to maximize the residence time available for the halogen-containing compound to be adsorbed onto the sorbent surface prior to the sorbent being ***injected into the flue gas duct***. This process maximizes the benefit and utilization of the halogen-containing reagent by placing it exactly where it is needed to facilitate ***elemental mercury*** removal—on the surface of the sorbent. The sorbent particles with their loading of adsorbed halogen-containing reagent ***enter the flue gas duct*** with high reactivity for the removal of elemental mercury.[552]

359. Additionally, Downs-Halogenation-Provisional discloses an alternative embodiment specifically directed to a HBr or Br_2 halogen-containing reagent that likewise provides four streams: "***a carbonaceous sorbent*** and ***halogen-containing reagent*** are brought together in the sorbent ***pneumatic transport line*** with sufficient residence time for the halogen-containing reagent to be adsorbed onto the carbonaceous sorbent particle before the sorbent is ***injected into the coal combustion flue gas stream***."[553]

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[552] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0022] (emphasis added); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at Fig. 2; Ex. 1015 (Downs-Halogenation) at ¶ [0019], Fig. 2.

[553] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0027] (emphasis added); *see also* Ex. 1015 (Downs-Halogenation) at ¶ [0024].

c. Element 1(c): "combining the first, second, and third streams wherein the halogen containing reagent is adsorbed onto the sorbent;"

360. Downs-Halogenation-Provisional discloses this element. Downs-Halogenation-Provisional discloses that the first stream (halogen-containing gas), second stream (injected PAC sorbent), and third stream (pneumatic transport conveying air) are combined, as follows, and that the halogen containing reagent is adsorbed onto the sorbent:

> The key aspect of the current invention is that a halogen-containing gas is injected into the flowing transport air/sorbent stream at a point close to the point where the sorbent and transport air first mix. This is done to maximize the residence time available for the halogen-containing compound to be adsorbed onto the sorbent surface prior to the sorbent being injected into the flue gas duct. .. . The sorbent particles with their loading of ***adsorbed*** halogen-containing reagent enter the flue gas duct with high reactivity for the removal of elemental mercury[554]

d. Element 1(d): "injecting the combined stream into the fourth stream:"

361. Downs-Halogenation-Provisional discloses this claim element. Downs states that the three streams, combined as per above, are injected into the flue gas. The flue gas is a stream containing mercury:

> The key aspect of the current invention is that a halogen-containing gas is injected into the flowing transport air/sorbent stream at a point close to the point where the sorbent and transport air first mix. This is done to maximize the residence

[554] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0022] (emphasis added); *see also* Ex. 1015 (Downs-Halogenation) at ¶ [0019].

time available for ***the halogen-containing compound to be adsorbed onto the sorbent*** surface prior to the sorbent being ***injected into the flue gas duct.***[555]

e. **Element 1(e): "adsorbing the elemental mercury onto the sorbent; and"**

362. Downs-Halogenation-Provisional discloses this element and acknowledges that it was well-known in the industry. Downs-Halogenation-Provisional states, "***Adsorption*** is a technique that has often been successfully applied for the separation and removal of trace quantities of undesirable components. … PAC injection removes both oxidized and ***elemental mercury*** species.[556]"

f. **Element l(f): "removing the sorbent from the fourth stream."**

363. Downs-Halogenation-Provisional discloses this element and identifies several well-known particulate emission control systems to remove sorbent from the mercury-containing gas (fourth stream). Particulate collectors, including "electrostatic precipitators (ESP) or fabric filters (FF), sometimes called baghouses, provide high-efficiency removal of particulate-bound mercury." [557] These particulate collectors remove the sorbent from the flue gas (i.e., fourth

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[555] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0022] (emphasis added); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising; placing a halogen-containing reagent on a sorbent surface prior to ***injecting the sorbent surface into the flue gas***.") (emphasis added); Ex. 1015 (Downs-Halogenation) at ¶ [0019].

[556] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [005] (emphasis added); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising; ***placing a halogen-containing reagent on a sorbent surface*** prior to injecting the sorbent surface into the flue gas.") (emphasis added); Ex. 1015 (Downs-Halogenation) at ¶ [0004].

[557] Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [004]; *see* Figs. 4-6; *see also* Ex. 1015 (Downs-Halogenation) at ¶ [0003], Figs. 4-6.

stream)[558]. In another embodiment, Downs-Halogenation-Provisional discloses that the "carbonaceous ***sorbent can be removed*** separately from the coal fly ash, if desired, by adding an additional particulate collector designed specifically to capture the injected quantity of carbonaceous sorbent."[559] Furthermore, Downs-Halogenation-Provisional notes that removal of sorbent is germane to PAC injection systems employed in the art at the time.[560]

B. EUEC CONFERENCES

364. The Electric Utilities Environment Conference ("EUEC") has been held annually since 1998. The primary purpose of EUEC was to facilitate information exchange, and to foster cooperation between industry, government, and regulatory stakeholders regarding environmental controls for electric utilities.[561] I personally attended the EUEC in 2005, 2006, 2007, 2009, 2010 and 2013. During these years, the EUEC included a focus on bringing together vendors and developers of mercury control technology with people who implemented that technology in utility companies. I delivered presentations at the 2005, 2006, 2007 and 2013 EUEC. The earliest three presentations were on Niksa Energy

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558 Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0025] ("During the tests flue gases exiting the SBS boiler … [passed] through a fabric filter for removal of fly ash and spent sorbent from the SDA FGD system."); *see also* Ex. 1015 (Downs-Halogenation) at ¶ [0022].

559 Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0033] (emphasis added); Ex. 1015 (Downs-Halogenation) at ¶ [0030].

560 Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [005] ("Many of the studies have focused on the injection of a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas stream to adsorb vapor-phase mercury. The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector."); *see also* Ex. 1015 (Downs-Halogenation) at ¶ [0004].

561 *See, e.g.*, Ex. 1061 (EUEC 2005 Home Page).

Associates' work on mercury emissions control, and the latest one was on catalyst poisoning in SCR units for NO_x control. My first-hand impressions are confined to the presentations and exhibits on mercury emissions control and related multipollutant control strategies in the years that I attended.

365. As an attendee of the 2005 EUEC and the 2006 EUEC, I received a CD for each year that included, among other items discussed in greater detail below, a PDF copy of a handout from the conference. Exhibit 1030 is a true and correct copy of the handout from the 2005 EUEC ("2005 EUEC Handout"). The 2005 EUEC Handout included an attendee list.[562] Exhibit 1047 is a true and correct copy of the handout from the 2006 EUEC ("2006 EUEC Handout"). The CD I received from the 2006 EUEC also included a separate PDF copy of the attendee list ("2006 EUEC Attendee List"). Exhibit 1049 is a true and correct copy of the 2006 EUEC Attendee List. [563] The 2005 EUEC Handout and 2006 EUEC Handout each included a searchable index of presenters—organized by subject matter to include a schedule (including both time and conference room) for their presentations—as well as the titles of their presentations, and an abstract summarizing their presentations. Exhibit 1030, 2005 EUEC Handout, was obtained from a CD that was mailed to me from the 2005 EUEC, as described

[562] Ex. 1030 (2005 EUEC Handout) at 106-18.
[563] Ex. 1049 (2006 EUEC Attendee List).

further below. Exhibit 1031 is a true and correct copy of the label and jacket of the CD that was mailed to me from the 2005 EUEC ("2005 EUEC CD Scan").[564]

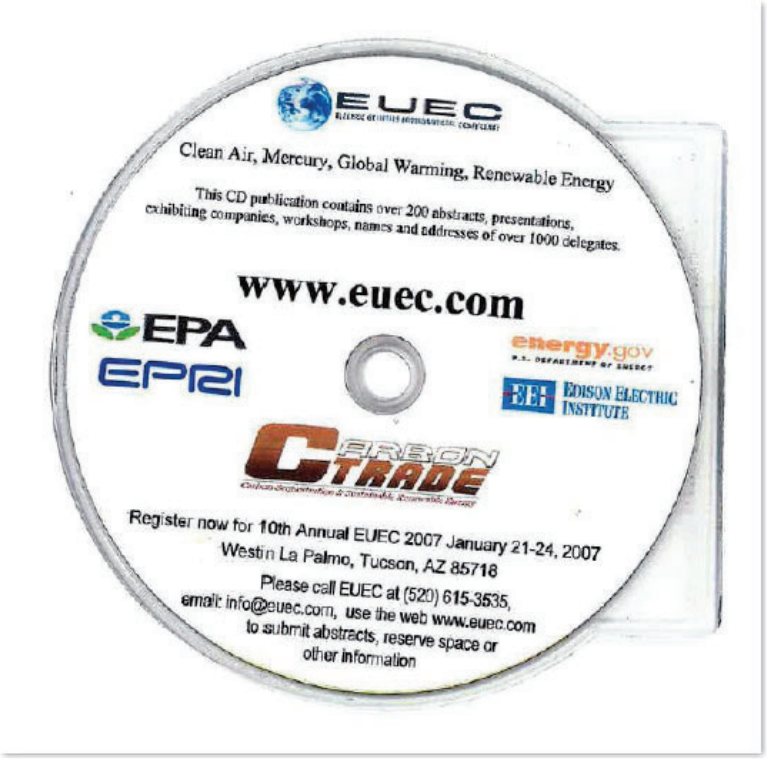


Exhibit 1047, 2006 EUEC Handout, was obtained from a CD that was mailed to me from the 2006 EUEC, as described further below. Exhibit 1048 is a true and correct copy of the label and jacket of the CD that was mailed to me from the 2006 EUEC ("2006 EUEC CD Scan"):

366. In the years I attended the EUEC, including 2005 and 2006, other EUEC attendees included business, sales, and project managers from the vendors, and engineers, compliance specialists, technical staff, and environmental control

[564] Ex. 1030 (2005 EUEC Handout).

managers from the utilities. There was also a sizeable representation of consultants and academic, government, and commercial researchers plying their services regarding environmental control and cleanup to both vendors and utility representatives, as well as project managers for government R&D programs.

367. Most presentations at EUEC were collaborations among a vendor, a utility, a field test team, and a funding agency. The population of speakers was largely drawn from the technical experts who actually performed mercury field tests, and some vendors also gave presentations that described their technology. Representatives from the U.S. funding agencies (such as DOE and EPA) occasionally delivered overview presentations on the general status of a single control technology, or performance comparisons among two or more control technologies.

368. The annual EUEC had two primary components: a very large selection of technical presentations in several distinct tracks, and a massive exhibition of technology vendors. The EUEC placed an emphasis on commercial applications of mercury control technology. This emphasis was evident in the presentations which, for the most part, were made by technology vendors, consulting companies, and teams of utility staff with technology vendors. Most presenters emphasized performance of mercury control technology in field tests instead of laboratory or theoretical data. Thus, the EUEC was particularly valuable as a

direct link from vendors of technologies and services for mercury emissions control and the engineers and technical staff at utilities who would ultimately implement and maintain these technologies and services.

369. My presentations on behalf of Niksa Energy Associates LLC related to mercury emissions control in 2005, 2006, and 2007. Those in 2005 and 2006 pertained to our latest calculations to estimate how FGD scrubbing and SCR units for NO control affected mercury emissions at the stack. Both topics were aspects of Niksa Energy Associates' ("NEA's") larger program to develop a predictive capability for mercury speciation as a component of complete gas cleaning systems for any coal type and furnace operating conditions. NEA's presentation in 2007 validated predicted mercury emissions with measured emissions for an assortment of complete utility gas cleaning configurations.

4. Prior Art Status of the 2005 EUEC Presentations

370. The 2005 EUEC took place on January 24-25, 2005 at the Westin La Paloma Resort, in Tucson, Arizona.[565] The conference included four separate presentation tracks: Track A — Air quality; Track B — Global Climate Change; Track C — Renewable Energy; and Track D — Other.[566] Each presenter prepared a Power-Point presentation that was presented at the conference. The conference compiled the presentations, and within a few weeks of the completion of the

[565] Ex. 1030 (EUEC Handout) at 2; Ex. 1061 (EUEC 2005 Home Page).
[566] Ex. 1030 (EUEC Handout) at 2.

conference, mailed a CD to all attendees that included all the presentations that were presented at the conference. I received the CD from the 2005 EUEC via mail in February 2005 ("EUEC CD Scan").[567]

371. I personally presented at the 2005 EUEC in Track A — Air Quality proceedings and attended most presentations for Track A — Air Quality proceedings.[568] An excerpt of the program schedule discussing my presentation is shown below: [569]

d. The Impact of Wet FGD Scrubbing On Hg Emissions From Coal-Fired Power Stations
Stephen Niksa – Niksa Energy Associates; Naoki Fujiwara – Coal Research Laboratory
Companies contemplating Hg control with wet FGDs need to know in advance how much of the Hg at the FGD inlet will be retained in the scrubber. This paper introduces a predictive capability for Hg retention in any Ca-based wet FGD, given Hg speciation at the FGD inlet, the flue gas composition, and the SO2 capture efficiency. A preliminary statistical analysis of data from 17 full-scale wet FGDs connects flue gas compositions, the extents of Hg oxidation at FGD inlets, and Hg retention efficiencies. These connections clearly signal that solution chemistry within the FGD determines Hg retention. A more thorough analysis based on thermochemical equilibrium yields highly accurate predictions for total Hg retention with no parameter adjustments. For the most reliable data, the predictions were within measurement uncertainties for both limestone and Mg/lime systems operating in both forced and natural oxidation mode. With the ICR database, the quantitative performance was almost as good for the most modern FGDs, which probably conform to the very high SO2 absorption efficiencies assumed in the calculations. The large discrepancies for older FGDs are tentatively attributed to the unspecified SO2 capture efficiencies and to the possible elimination of HCl in prescrubbers. The equilibrium calculations suggest that Hg retention is most sensitive to inlet HCl and O2 levels; weakly dependent on SO2 capture efficiency; and insensitive to HgCl2, NO, Ca/S ratio, and slurry dilution level in limestone FGDs, and to MgSO3 levels in Mg/lime systems. Consequently, systems with prescrubbers to eliminate HCl probably retain less Hg than fully integrated FGDs. The analysis also predicts re-emission of Hg0, but only for wide variations in the inlet O2 to levels that are much lower than those in full-scale FGDs.

As a result of my attendance, as noted above, I received a CD including PDFs of all presentations and other program materials. A scan of the front of that CD from my personal files is attached to this declaration.[570]

[567] Ex. 1031 (EUEC CD Scan).
[568] Ex. 1030 (EUEC Handout) at 2.
[569] Ex. 1030 (EUEC Handout) at 32.
[570] Ex. 1031 (EUEC CD Scan).

372. In addition to myself, over 800 people attended the 2005 EUEC, as described in the attendee list included in the EUEC Handout.[571] As with the other EUEC conferences, many people who would qualify as a person of skill in the art attended the 2005 EUEC, including from such notable organizations as U.S. Department of Energy, EPRI, ADA-ES Inc., URS Corporation, Southern Company, ALSTOM Power, and many others. In particular, I recall that approximately 250 to 300 people attended the Track A meetings, and the attendees of Track A included engineers, regulatory compliance specialists, and project managers from utilities; engineers and technicians from labs and testing organizations; technical staff from R&D organizations; and sales managers and representatives from technology vendors.

373. During the Track A — Air Quality proceedings of the 2005 EUEC, two presentations were given that are discussed in greater detail below. The first presentation was "Full-Scale Evaluations of Mercury Control Technologies with PRB Coals" presented by employees at ADA-ES Inc. and naming Sharon Sjostrom as the lead researcher.[572] A copy of that presentation, as provided to me in the CD I received from EUEC, and has been provided as Exhibit 1010 (hereinafter "Sjostrom"). The subject matter of the presentation from the CD mailed to me and

[571] Ex. 1030 (EUEC Handout) at 106-118.
[572] Ex. 1030 (EUEC Handout) at 23.

the other conference attendees, as reflected in Sjostrom, correlates with the presentation I attended at the 2005 EUEC.[573]

374. The second presentation delivered during the Track A —Air Quality proceedings of the 2005 EUEC was "Mercury Control Evaluation of Halogen Injection into a Texas Lignite-Fired Boiler," presented by employees of Texas Genco and naming Craig Eckberg as the lead researcher.[574] A copy of that presentation, as provided to me in the CD I received from EUEC, has been provided as Exhibit 1011 (hereinafter "Eckberg"). The subject matter of the presentation from the CD mailed to me and the other conference attendees, as reflected in Sjostrom, correlates with the presentation I attended at the 2005 EUEC.[575]

375. Both Eckberg and Sjostrom were delivered during the A3 session—a particular subset of Track A that was devoted to "Mercury —Control"—which took place between 7:30 and 9:30 am on January 25, 2005.[576] The attendees for the A3 session were generally the same as those described above with regards to Track A as a whole. In fact, Sjostrom and Eckberg were presented consecutively, in the same room.[577] The Sjostrom EUEC presentation was slotted as presentation

[573] Ex 1010 (Sjostrom).
[574] Ex. 1030 (EUEC Handout) at 23.
[575] Ex 1011 (Eckberg).
[576] Ex. 1030 (EUEC Handout) at 23.
[577] Ex. 1030 (EUEC Handout) at 23.

number A3b, and the Eckberg EUEC presentation was slotted as presentation number A3c.[578]

1. Prior Art Status of the 2006 EUEC Presentations

376. The 2006 EUEC took place on January 22-25, 2006 at the Westin La Paloma Resort in Tucson, Arizona.[579] The conference included four separate presentation tracks: Track A – Clean Air CAIR; Track B – Mercury CAMR; Track C – Global Warming; Track D – Renewable Energy, and Track E – EHS EMIS.[580] Each presenter prepared a Power-Point presentation that was presented at the conference. The conference compiled the presentations, and within a few weeks of the completion of the conference, mailed a CD to all attendees that included all the presentations that were presented at the conference. I received the CD from the 2006 EUEC via mail in February 2006 ("2006 EUEC CD Scan").[581]

377. I personally presented at the 2006 EUEC in Track B – Mercury CAMR proceedings and attended most presentations for Track B – Mercury CAMR proceedings.[582]'" An excerpt of the program schedule discussing my presentation is shown below:[583]

[578] Ex. 1030 (EUEC Handout) at 23.
[579] Ex. 1047 (2006 EUEC Handout) at exhibit page 1; Ex. 1050 (EUEC 2006 Home Page).
[580] Ex. 1047 (2006 EUEC Handout) at exhibit page 1.
[581] Ex. 1048 (2006 EUEC CD Scan).
[582] Ex. 1047 (2006 EUEC Handout) at exhibit page 1.
[583] Ex. 1047 (2006 EUEC Handout) at exhibit page 27.

B6.1. A Predictive Mechanism for Mercury Oxidation On SCR Catalysts – *Stephen Niksa and Naoki Fujiwara; Niksa Energy Associates*
This paper introduces a predictive mechanism for Hg0 oxidation on SCR catalysis in coal-fired utility gas cleaning systems, given the NH3/NO ratio and concentrations of Hg0 and HCl at the monolith inlet; the monolith pitch and channel shape; and the SCR temperature and space velocity. A simple premise connects the established mechanism for catalytic NO reduction to the Hg0 oxidation behavior on SCRs: That HCl competes for surface sites with NH3, and that Hg0 contacts these chlorinated sites either from the gas phase or as a weakly adsorbed species. This mechanism explicitly accounts for the inhibition of Hg0 oxidation by NH3, so that the monolith sustains two chemically distinct regions. In the inlet region, strong NH3 adsorption minimizes the coverage of chlorinated surface sites, so NO reduction inhibits Hg0 oxidation. But once NH3 has been consumed, the Hg0 oxidation rate rapidly accelerates, even while the HCl concentration in the gas phase is uniform. Factors that shorten the length of the NO reduction region, such as smaller channel pitches and converting from square to circular channels, and factors that enhance surface chlorination, such as higher inlet HCl concentrations and lower NH3/NO ratios, promote Hg0 oxidation. This mechanism accurately interprets the reported tendencies for greater extents of Hg0 oxidation on honeycomb monoliths with smaller channel pitches and hotter temperatures, and the tendency for lower extents of Hg0 oxidation for hotter temperatures on plate monoliths. The mechanism also depicts the inhibition of Hg0 oxidation by NH3 for NH3/NO ratios from zero to 0.9. Perhaps most important for practical applications, the mechanism reproduces the reported extents of Hg0 oxidation on a single catalyst for four coals that generated HCl concentrations from 8 to 241 ppm, which covers the entire range encountered in the U.S. utility industry. Similar performance is also demonstrated for full-scale SCRs with diverse coal types and operating conditions.

As a result of my attendance, as noted above, I received a CD including PDFs of all presentations and other program materials. A scan of the front of that CD from my personal files is reproduced below and attached to this declaration.[584]



271. In addition to myself, over 1000 people attended the 2006 EUEC, as described in the 2006 Attendee List.[585] As with the other EUEC conferences, many

584 Ex. 1048 (2006 EUEC CD Scan).
585 Ex. 1049 (2006 EUEC Attendee List) at exhibit pages 1-30.

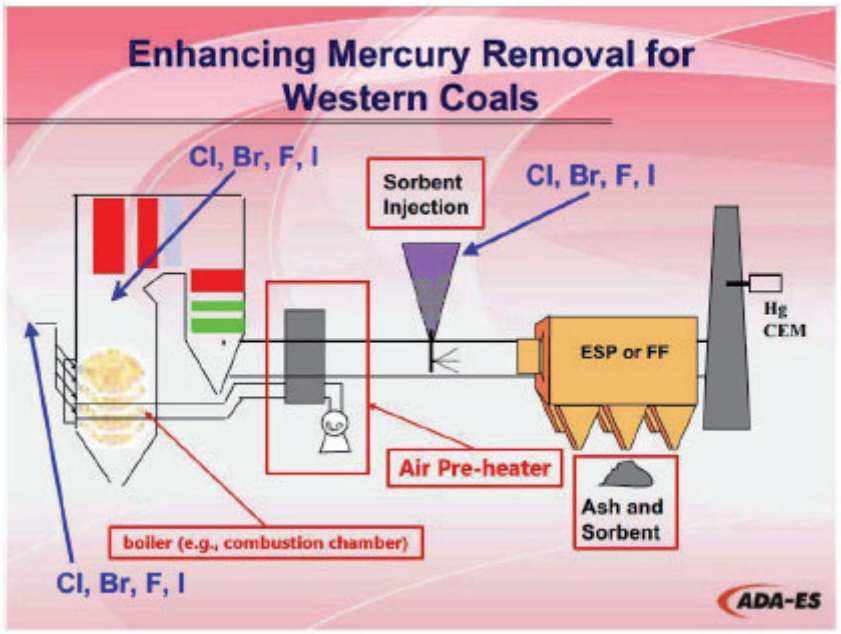
people who would qualify as a person of skill in the art attended the 2006 EUEC, including from such notable organizations as U.S. Department of Energy, EPRI, ADA-ES Inc., URS Corporation, Southern Company, ALSTOM Power, and many others. In particular, I recall that approximately 300 to 350 people attended the Track B meetings, and the attendees of Track B included engineers, regulatory compliance specialists, and project managers from utilities; engineers and technicians from labs and testing organizations; technical staff from R&D organizations; and sales managers and representatives from technology vendors.

378. During the Track B – Mercury CAMR proceedings of the 2006 EUEC, one presentation was given that is discussed in greater detail below. That presentation was "Integrated Approach to Multi-Pollutant Control" presented by employees at GE Environmental and naming Vitali Lissianski as the lead researcher.[586] A copy of that presentation, as provided to me in the CD I received from EUEC, has been provided as Exhibit 2014 (hereinafter "Lissianski-Presentation"). The subject matter of the presentation from the CD mailed to me and the other conference attendees, as reflected in Lissianski-Presentation, correlates with the presentation I attended at the 2006 EUEC.[587]

2. Overview of the Disclosure of Siostrom

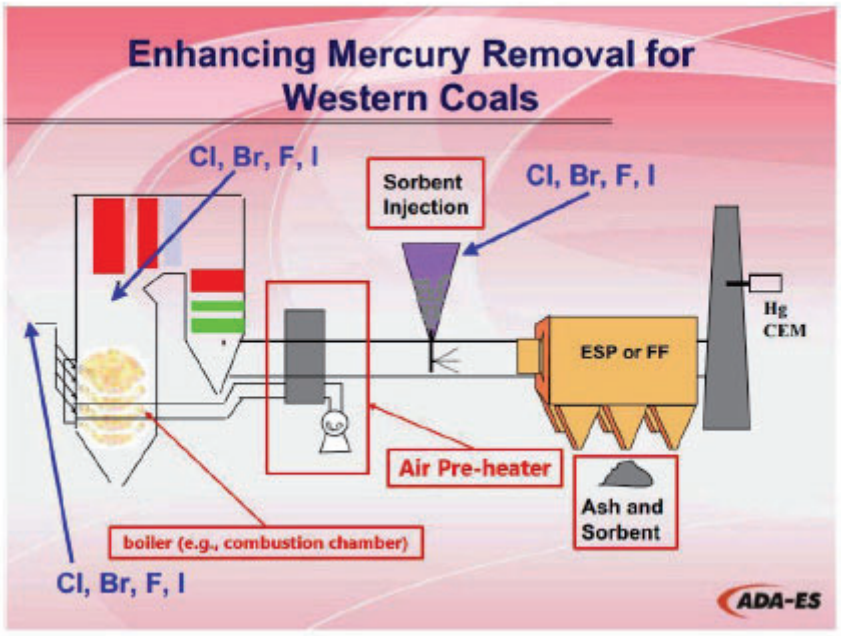
[586] Ex. 1047 (2006 EUEC Handout) at exhibit page 24.
[587] Ex. 2014 (Lissianski-Presentation).

379. Sjostrom discussed the results of full-scale testing that was focused on increasing the halogen, particularly bromine, concentration in coal-fired power plant flue gas for the purpose of mercury removal from the flue gas. Sjostrom discloses multiple methods of introducing the halogens, and discussed "the effect on mercury emissions of 1) blending PRB [Powder River Basin coal] with bituminous coal, 2) injecting alternative sorbents specifically designed to operate in a halogen deficient flue gas, and 3) injecting chemical additives onto the coal."[588] Sjostrom describes testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection as detailed below.[589]



[588] Ex. 1030 (2005 EUEC Handout) at 23.
[589] Ex. 1010 (Sjostrom) at 4.

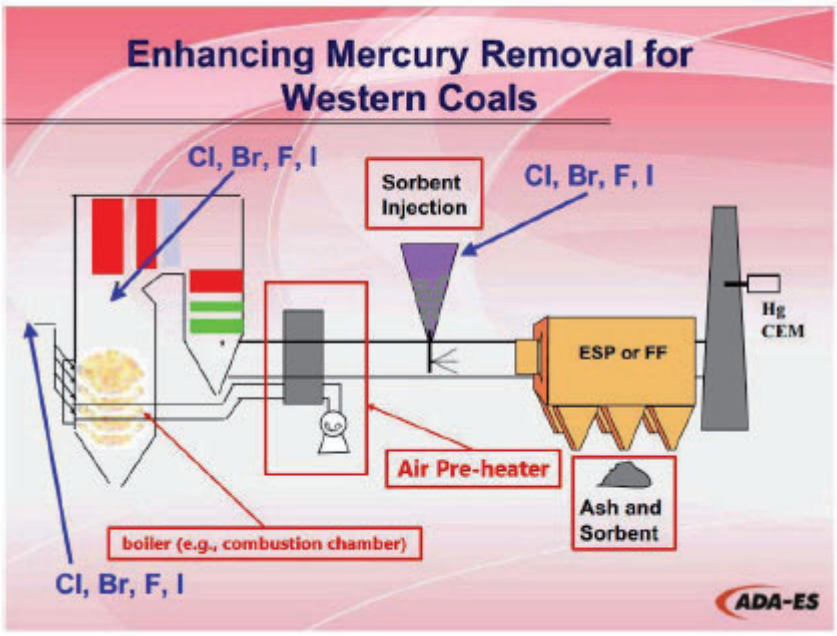
380. Sjostrom describes various mercury control tests conducted at coal-fired power plants.[590] Both plants involve combustion of coal in a coal-fired boiler 423 (e.g., combustion chamber), as shown in the annotated version of the same figure below.[591]



A POSITA would have understood that this unit was a boiler based on the image used to represent the unit in the drawing, which was a common and routine way to draw a coal-combustion boiler.

381. Sjostrom discloses testing at coal-fired power plants that also include an air pre-heater as shown in the annotated version of the same figure below.[592]

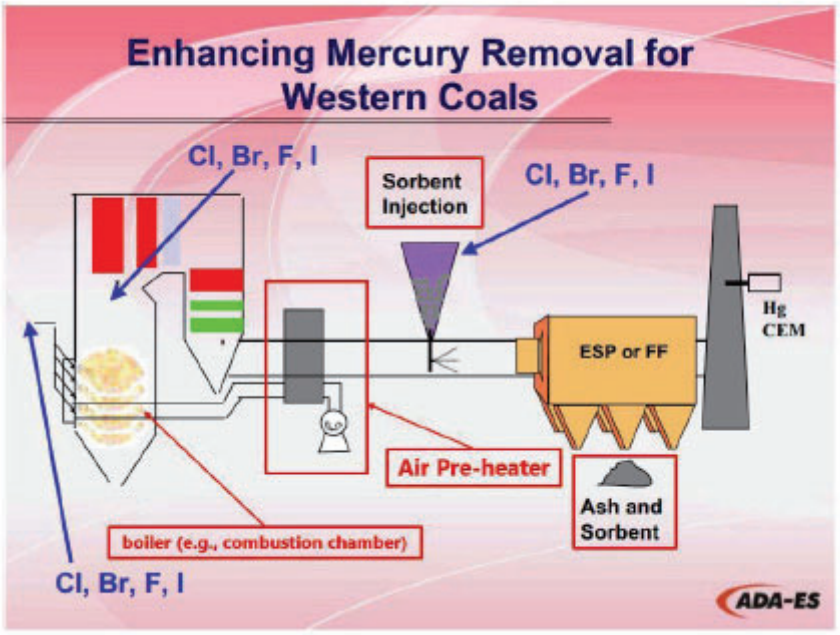
590 Ex. 1010 (Sjostrom) at 12, 18.
591 Ex. 1010 (Sjostrom) at 4 (annotations in red).
592 Ex. 1010 (Sjostrom) at 4 (annotations in red).



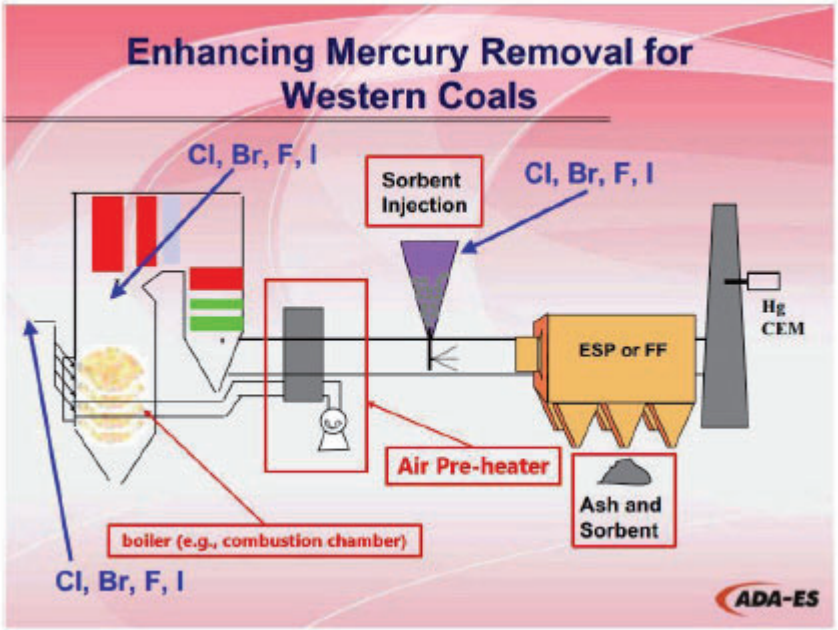
A POSITA would have understood that the labeled component is an air pre-heater based on the image used to portray the unit on the schematic of Sjostrom. For example, the image includes a fan connected to a flow-path loop going into the inlet of the boiler to mix preheated air and coal. The gray box indicates the heat-transfer zone where the air pre-heater transfers heat to the air from the flue gas leaving the boiler.

382. The system of Sjostrom also includes a sorbent injection unit downstream of the boiler (labeled "Sorbent Injection"), as shown in the annotated version of the same figure below.[593]

[593] Ex. 1010 (Sjostrom) at 4 (annotations in red).



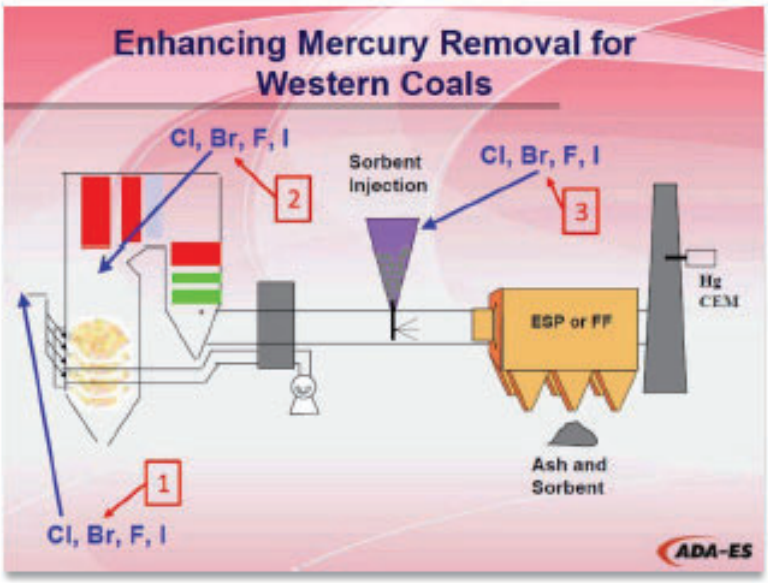
383. As shown in the annotated version of the figure below, Sjostrom describes passing the flue gas through an electrostatic precipitator ("ESP") or fabric filter ("FF").[594]



[594] Ex. 1010 (Sjostrom) at 4 (annotations in red).

This annotated figure from Sjostrom specifically shows that particulate matter, including the mercury-sorbent composition, would have been separated from the flue gas by the ESP or FF (fabric filter), because a POSITA would have understood that it was well-known to use an ESP or FF to separate such solid materials from the flue gas.[595]

384. Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[596] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected within the process in multiple locations (those locations are annotated and numbered in red in the same figure being discussed here).[597]



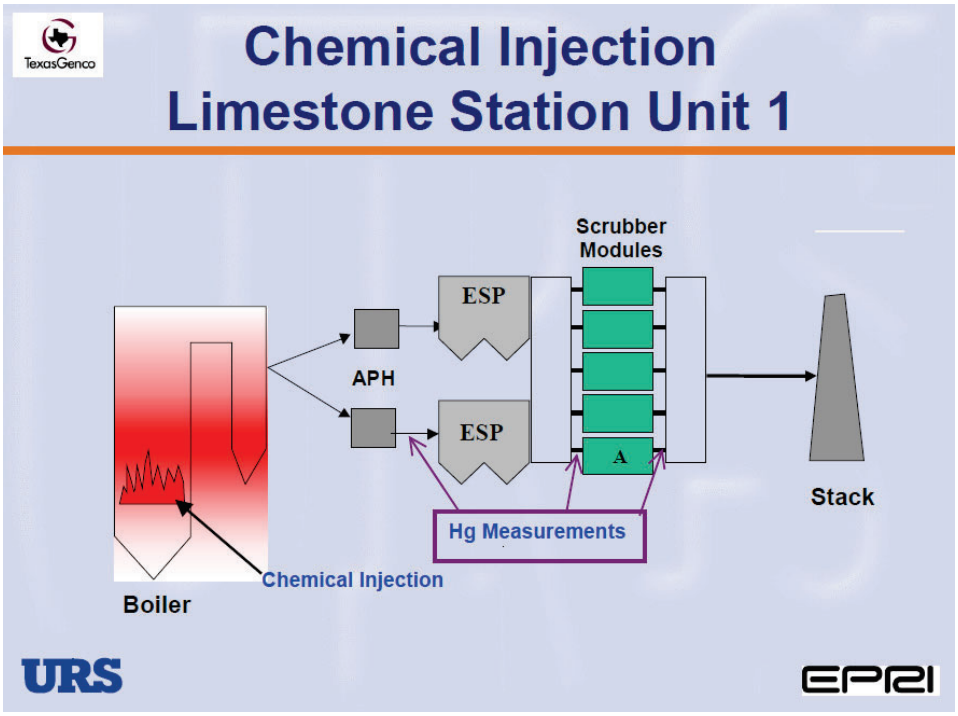
[595] *See* State of the Art, above, §VIII.B.5.
[596] Ex. 1010 (Sjostrom) at 10-11.
[597] Ex. 1010 (Sjostrom) at 4 (annotations in red).

Addition Location 1 of Sjostrom teaches adding bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[598] Addition Location 2 of Sjostrom teaches injecting bromine into the combustion chamber.[599] Addition Location 3 of Sjostrom teaches adding bromine to the mercury sorbent that is injected into the flue gas.[600]

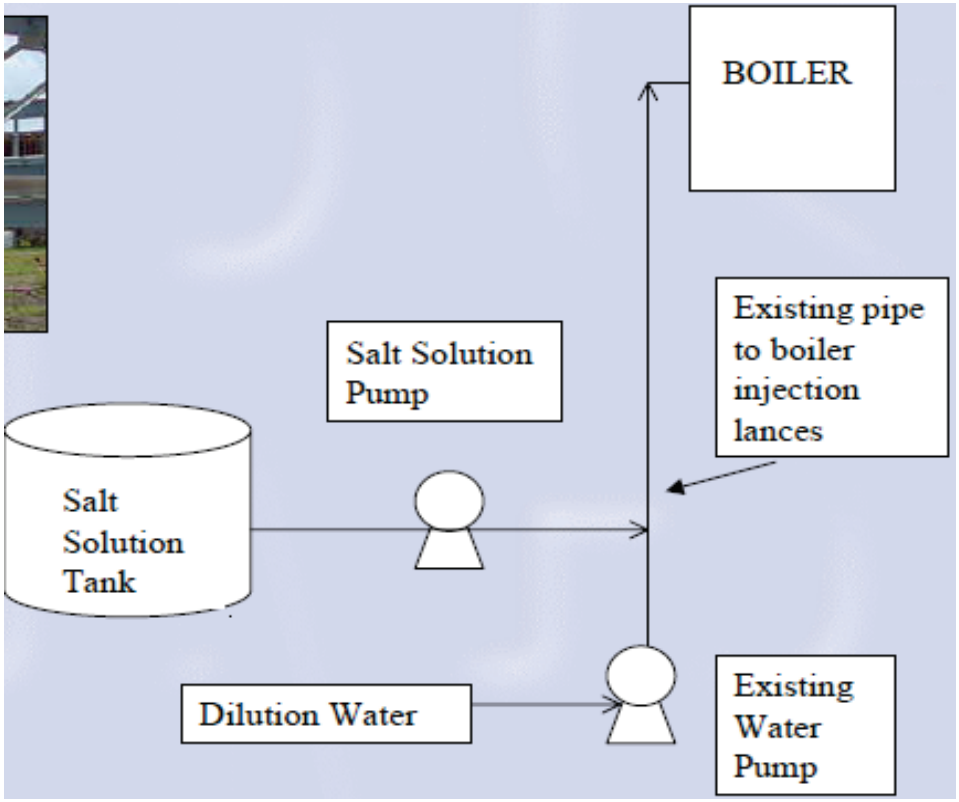
5. Overview of the Disclosure of Eckberg

385. Eckberg, which was presented immediately after Sjostrom at the 2005 EUEC, also disclosed the use of halogens to remove mercury from coal-fired plants. Eckberg provided data that showed "how halogen injection technology affects mercury removal and oxidation across an ESP in Texas Lignite flue gas.[601] As shown in the figure below, Eckberg describes testing the mercury removal effects of "Chemical Injection" of a halogen directly into a coal-fired combustion chamber (labeled "boiler").[602]

[598] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[599] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[600] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[601] Ex. 1030 (EUEC Handout) at 24.
[602] Ex. 1011 (Eckberg) at 5.



386. Eckberg also includes a schematic showing the injection equipment used for the chemical injection.[603]



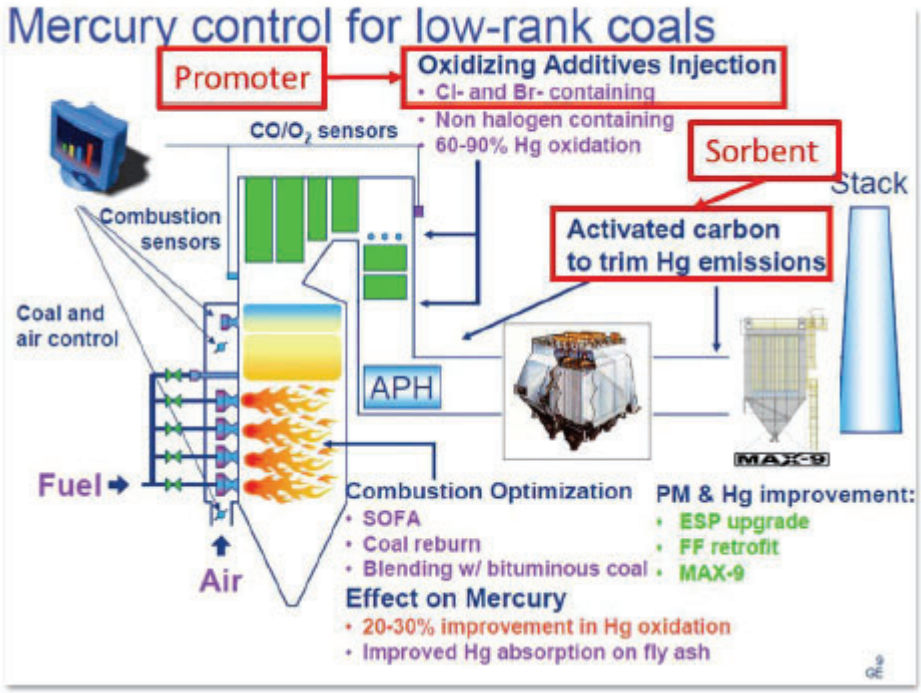
[603] Ex. 1011 (Eckberg) at 8.

In particular, the halogens were maintained in an aqueous solution (labeled "Salt Solution Tank"), then pumped into a transport line where they were diluted with additional water ("Dilution Water"), followed by injection directly into the combustion chamber ("Boiler"). Eckberg explains that the "salt solution" injected into the boiler was either "$CaCl_2$ (25 wt%)" or "$CaBr_2$ (52 Wt%)."[604] $CaBr_2$ refers to calcium bromide, and the 52 wt% means that of the solution, 52% by weight was calcium bromide, and 48% was water. Eckberg further discloses the ratio of bromine to coal, the feed rate of the aqueous salt solution (in gallons per minute), and the estimated gas-phase concentration (in ppm) of HBr in the mercury-containing flue gas.[605]

3. Overview of the Disclosure of Lissianski-Presentation

387. Lissianski-Presentation also disclosed removal of mercury from coal-fired plants. Specifically, the annotated figure of Lissianski-Presentation below describes removing mercury from flue gas of coal-fired power plants using sorbent and promoter injection.[606]

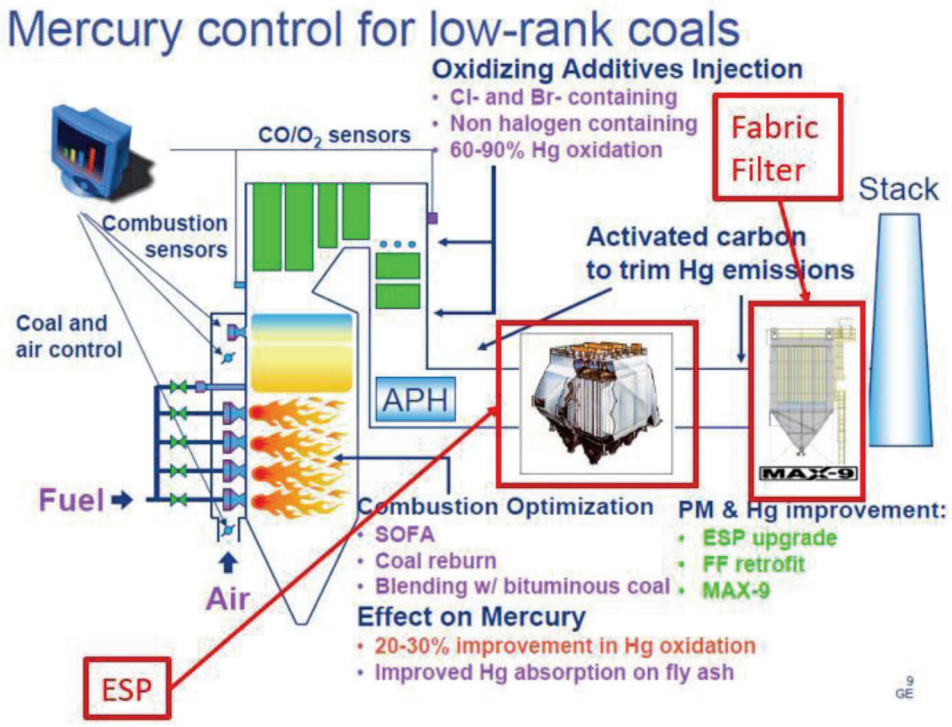
[604] Ex. 1011 (Eckberg) at 9.
[605] Ex. 1011 (Eckberg) at 9.
[606] Ex. 2014 (Lissianski-Presentation) at 9 (annotations in red).



As shown in the figure above, Lissianski-Presentation describes injecting Cl-containing and Br-containing promoters that result in "60-90% Hg oxidation," and injecting "activated carbon" as a sorbent "to trim Hg emissions."[607] Lissianski-Presentation also discloses the use of "Darco FGD" as an exemplary activated-carbon sorbent for injection.[608]

[607] Ex. 2014 (Lissianski-Presentation) at 9.
[608] Ex. 2014 (Lissianski-Presentation) at 8; see also Ex. 2014 (Lissianski-Presentation) at 18 ("Darco Hg")

388. Lissianski-Presentation describes injecting the "Cl- and Br- containing" promoters into the flue gas before the APH (air preheater).[609] The annotated figure of Lissianski-Presentation below shows activated carbon injection before an ESP or between an ESP a fabric filter (or baghouse).[610]



L. EPA-PROPOSAL

1. Prior Art Status of the EPA-Proposal

389. I understand that the EPA-Proposal was published in the January 30, 2004 edition of the Federal Register, in volume 69, no. 20, on pages 4652-4752.

2. Overview of the Disclosure of EPA-Proposal

609 Ex. 2014 (Lissianski-Presentation) at 9.
610 Ex. 2014 (Lissianski-Presentation) at 9.

390. As described in State of the Art regarding EPA Regulations to Reduce Mercury Emissions, in the lead-up to official passage of the Clean Air Mercury Rule (CAMR) in 2005, the industry was put on notice of the upcoming rule. As part of that proposal, on December 15, 2003, the EPA signed proposed rules and published them on January 30, 2004 in the Federal Register.[611] The proposed rules stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018.[612]

391. As part of the proposed rules, the EPA addressed achieving mercury removal "beyond-the-floor" for both existing units and new units. The EPA clarified that "beyond-the-floor" options referred to "available regulatory options (i.e., technologies or work practices) that were more stringent than the MACT floor level of control for each of the different subcategories."[613] The acronym "MACT" refers to "maximum achievable control technology."[614] In the regulatory context, MACT pertains to the minimum emissions that regulators can reasonably require. As such, this limiting threshold is sometimes called a floor. Notwithstanding, EPA's regulatory process was often called upon to consider proposing regulations that are even more stringent than MACT, for example, to anticipate control technologies that have not yet been certified as MACT but nonetheless have the potential to enable

[611] Ex. 1009 (EPA-Proposal) at 4716-4752 (to be amended at 40 C.F.R. pts. 60, 63).
[612] Ex. 1009 (EPA-Proposal) at 4698.
[613] Ex. 1009 (EPA-Proposal) at 4675.
[614] Ex. 1009 (EPA-Proposal) at 4652.

more stringent emissions control. In this sense, EPA-Proposal addresses whether EPA has considered regulating Hg emissions beyond the MACT floor level of control.

392. The EPA-Proposal discusses several ways to reduce mercury emissions to a desired level, such as the 70% floor, including by injecting activated-carbon sorbent material (bare or impregnated with halides), and controlling the sorbent injection rate to achieve the desired level of mercury removal. For example, the EPA-Proposal describes "sorbent injection" to introduce sorbent into the flue gas. "Sorbents can be introduced by two basic methods: by channeling flue gas through a bed of sorbent or by direct sorbent injection."[615] With sorbent injection, "after sorbent is introduced into the flue gas, it adsorbs Hg and other contaminants and is captured downstream in an existing or sorbent-specific PM [(particulate matter)] control device."[616] The EPA specifically mentions "activated carbon" as an example of a sorbent that can be injected into a flue gas.[617] The EPA recognized "two basic types of activated carbon (AC; regular and impregnated)" that were suitable candidates for achieving desired mercury reductions.[618] The "impregnated" activated

[615] Ex. 1009 (EPA-Proposal) at 4676.
[616] Ex. 1009 (EPA-Proposal) at 4676.
[617] Ex. 1009 (EPA-Proposal) at 4676.
[618] Ex. 1009 (EPA-Proposal) at 4676.

carbons refer to those that are "supplemented with chemicals," such as "Cl [(chlorine)], sulfur, and iodide."[619]

C. THE OLSON-PAPER REFERENCE

393. Inventors Edwin S. Olson, Michael J. Holmes, and John H. Pavlish are listed as coauthors on Olson et al., "Chemical mechanisms in mercury emission control technologies," J. Phys. IV France 107 (2003), presented May 26-30, 2003 and the XIIth International Conference on Heavy Metals in the Environment in Grenoble, France **("Olson-Paper")**.[620] Olson-Paper relates generally to using halogens to promote activated carbon for the purpose of reducing elemental mercury emissions in flue gas from coal-burning power plants.[621]

1. Prior-Art Status of Olson-Paper

394. I have reviewed the declaration of Dr. James Mullins, Exhibit 1092, whom I understand is a librarian expert that had previously worked at MIT libraries. I understand that Olson-Paper, Exhibit 1079, is an authentic copy that was published in May 2003 in Volume 107 of the Journal de Physique IV.[622] I further understand that Olson-Paper was indexed and publicly accessible from the MIT Libraries no later than June 26, 2003.[623] I understand that Olson-Paper was indexed publicly accessible from multiple other libraries in 2003, including:

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619 Ex. 1009 (EPA-Proposal) at 4676.
620 Ex. 1079 (Olson-Paper).
621 Ex. 1079 (Olson-Paper) at Abstract.
622 Ex. 1092 (Mullins Decl.) at ¶38-52, 79.
623 Ex. 1092 (Mullins Decl.) at ¶53-65, 79.

from the University of Wisconsin-Madison no later than June 27, 2003; from Brown University no later than Sept. 8, 2003; and from Library of Congress later than November 3, 2003.[624] I understand from Dr. Mullins' declaration that Olson-Paper could have been found, among other methods, by the subject of "Heavy Metals — Environmental Aspects."[625] A POSITA would have understood that mercury was a "heavy metal," and in fact one of the most problematic and heavily investigated heavy metals for purposes of "environmental" harm.

2. Overview of the Disclosure of Olson-Paper

395. Olson-Paper describes the surface structure of activated carbon, and proposed chemical reaction mechanisms between halogens, activated carbon, and mercury. The field of endeavor in Olson-Paper is improving the ability of activated carbon to adsorb mercury.

396. Olson-Paper explains, "Mercury emissions in flue gas from coal-burning utilities are a major environmental concern.[626]" Olson-Paper acknowledges that prior "control technologies for utilities to meet the emission regulations have focused mainly on the injection of powdered sorbents into the duct where they capture the mercury in the flue gas and are subsequently collected with the

624 Ex. 1092 (Mullins Decl.) at ¶66-78, 79.
625 Ex. 1092 (Mullins Decl.) at ¶53-79.
626 Ex. 1079 (Olson-Paper) at 979.

particulates in a bag filter or an electrostatic precipitator."[627] Olson-Paper explains that powdered activated carbon may be an effective mercury sorbent, but notes that "further advances in understanding the chemisorption mechanisms are needed for the design of carbons with faster kinetics and greater capacities."[628] Thus, Olson-Paper focuses on "[o]xidation and capture of elemental mercury on activated carbon … in a variety of flue gas atmospheres."'[629] Olson-Paper proposes chemical reaction mechanisms for the reactions between: (a) activated carbon and elemental mercury (Hg^0); and (b) activated carbon and oxidized mercury (Hg^{2+} or Hg(II)).

397. Olson-Paper describes that both types of mercury species—elemental mercury (Hg^0) and oxidized mercury (Hg(II))—are present in the flue gas, stating that "[t]he speciation of mercury present in the flue gas significantly affects the ability of a sorbent to capture the mercury."[630] Specifically, Olson-Paper explains that "[e]lemental mercury (Hg^0) has a much higher vapor pressure and has no affinity for basic surfaces, whereas oxidized mercury, i.e., Hg(II) compounds, such as mercuric chloride and mercuric nitrate, are less volatile and stick easily to a basic surface.[631]" Thus, Olson-Paper concludes that "for a flue gas

627 Ex. 1079 (Olson-Paper) at 979.
628 Ex. 1079 (Olson-Paper) at 979.
629 Ex. 1079 (Olson-Paper) at 979.
630 Ex. 1079 (Olson-Paper) at 979.
631 Ex. 1079 (Olson-Paper) at 979.

containing high Hg^0 concentrations, a sorbent must effect a chemisorption process resulting in formation of a Hg(II) species that can bond to the sorbent (or be trapped in a subsequent scrubber)."[632]

a. Graphene sheets with carbene edge sites

398. Reporting the work of earlier researchers, Olson-Paper describes that activated carbon, such as that sold under the commercial name Norit FGD, contains graphene sheets having carbene species edge sites. His model describes "a zig-zag *carbene site on the carbon edge* that performs as a Lewis base."'[633] Olson-Paper elaborates regarding the "carbene structures" present "at the edges of the carbon graphene layers [8]" in activated carbon.[634] For this proposition, Olson-Paper cites to the work of Radovic, reference 8, who had investigated "the surface chemistry of edge carbon atoms" in graphene layers and "argue in favor of" "carbene or m-benzyne at the zigzag sites[635]." The carbene species edge site is labeled by Olson-Paper as "Carbon Basic Zig-Zag Site," and circled below:"[636]

[632] Ex. 1079 (Olson-Paper) at 979-80.
[633] Ex. 1079 (Olson-Paper) at 979 (Abstract).
[634] Ex. 1079 (Olson-Paper) at 982.
[635] Ex. 1046 (Radovic).
[636] Ex. 1079 (Olson-Paper) at 982.

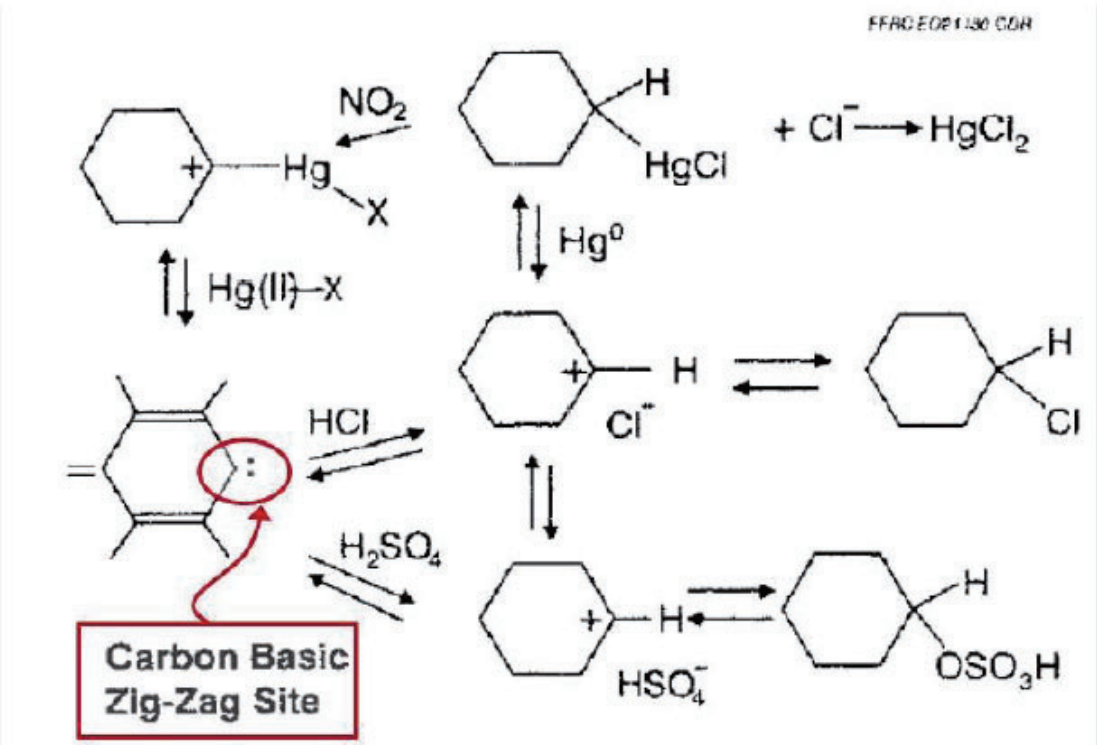


Figure 2. Reaction site model for activated carbon.

b. **Reacting halogen-containing promoter with activated carbon sorbent to form a carbocation prepared with a bromide anion, and chemically reacting promoted sorbent with elemental mercury**

399. Investigating the Norit FGD brand-name of powdered activated carbon sorbent, Olson-Paper performed several tests with HCl (hydrogen chloride) and prepared two types of mercury/sorbent compositions:

- by binding to the activated carbon to promote the activated carbon, such that the *promoted sites of the activated carbon* capture *elemental* mercury; and

- by oxidizing the mercury, such that the *basic binding sites of the activated carbon* capture the *oxidized* mercury.

The first pathway proposed by Olson-Paper is designated by steps 1 and 2 to produce mercury/sorbent composition "B" in annotated Fig. 2 of Olson-Paper, below. The second pathway proposed by Olson-Paper is labeled as step 3 to produce mercury/sorbent composition "A."

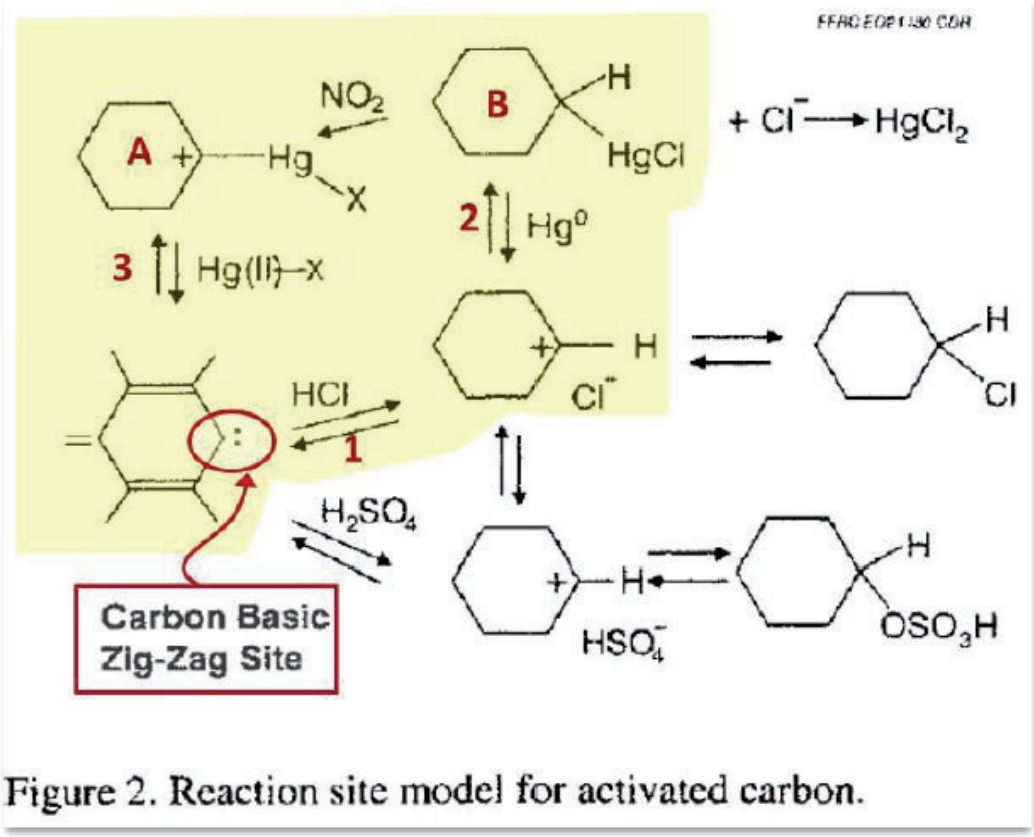


Figure 2. Reaction site model for activated carbon.

In each proposed mechanism, the basic binding sites of the activated carbon are labeled by Olson-Paper as "Carbon Basic Zig-Zag Site," and are circled in red above. These are the "carbene" species referred to earlier, as shown by the lone pair of electrons (circled in red). The hexagon to which the carbene species is bound is an

aromatic ring, as described in Section VIII.C.2. above, and graphene is formed from sheets of such aromatic rings.

400. Regarding steps 1 and 2, Olson-Paper describes that the "basic carbene cannot react directly with Hg^0, but reacts with HCl to form stable carbenium ion intermediates, which are then active for binding Hg^0, accepting electrons from the atom (Figure 2). Thus HCl or other acids promote the oxidation step.[637] Hg^0 refers to elemental mercury (i.e., non-oxidized mercury). A person of skill in the art would have recognized that the "carbenium ion intermediates" disclosed in Olson-Paper refers to a "carbocation." This carbenium ion intermediate, or carbocation, oxidizes mercury, according to Olson-Paper. Below is an annotated Figure 2 from Olson-Paper, showing formation of the carbocation (step 1) and oxidation of the elemental mercury (step 2):[638]

[637] Ex. 1079 (Olson-Paper) at 982.
[638] Ex. 1079 (Olson-Paper) at 982, Fig. 2.

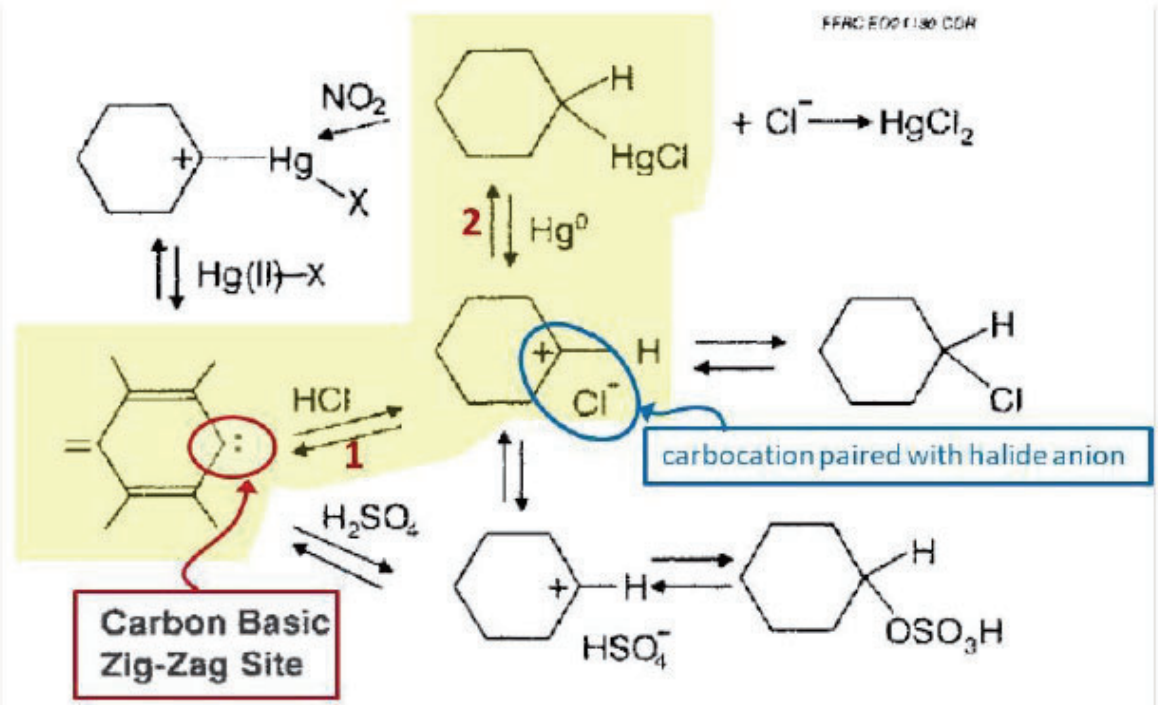


Figure 2. Reaction site model for activated carbon.

The carbocation is indicated by the (+), and the anion is indicated by the (Cl^-). The carbocation paired with the halide (in this case, chloride) anion then reacts with elemental mercury (Hg^0), in step 2.

401. Regarding the chemical reaction between activated carbon and oxidized mercury—what is labeled as step 3 and mercury/sorbent composition "A"—Olson-Paper describes that "*basic sites* on carbon that are responsible for *binding the Lewis acid Hg(II)*."[639] The Hg(II) refers to oxidized mercury, and the

[639] Ex. 1079 (Olson-Paper) at 981.

designation of "Lewis acid" means that the oxidized mercury can accept electrons (i.e., from the carbene species at the edge sites of the graphene sheets).

402. As further confirmation that my analysis of the disclosure of Olson-Paper is correct, I note that the depiction of the two reaction mechanisms are nearly identical between Olson-Paper (top)[640] and the '147 Patent (bottom)[641].

[640] Ex. 1079 (Olson-Paper) at 982, Fig. 2.
[641] Ex. 1001 ('147 Patent) at Fig. 2.

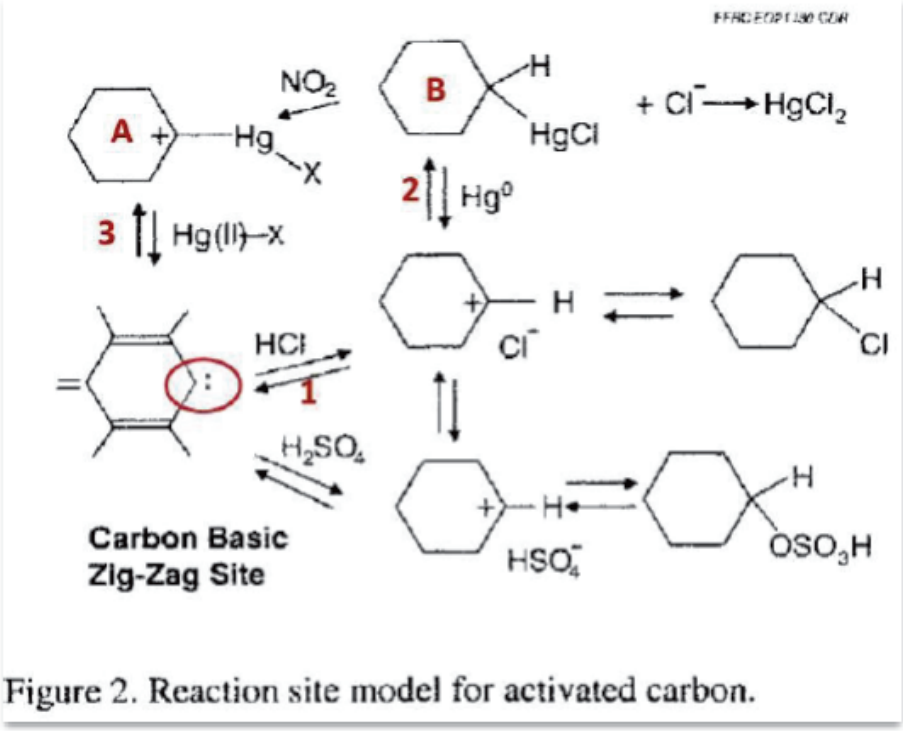


Figure 2. Reaction site model for activated carbon.

Ex[1079]

D. THE LISSIANSKI-PATENT REFERENCE

403. Ex. 1036 ("Lissianski-Patent") is U.S. Patent No. 7,514,052, which names Vitali Victor Lissianski as the sole inventor, and was assigned to General Electric Company. Lissianski-Patent is entitled, "Method for Removal of Mercury Emissions from Coal Combustion[642]"

[642] Ex. 1036 (Lissianski-Patent) at Title.

1. Prior-Art Status of Lissianski-Patent

404. Lissianski-Patent was issued by the USPTO on April 7, 2009, from U.S. Patent Application No. 10/751,496, which was filed Jan. 6, 2004. Accordingly, I understand that Lissianski-Patent qualifies as prior art at least as of Jan. 6, 2004. Lissianski-Patent is cited on the cover of the Challenged Patent. However, the USPTO examiner was not presented with other prior-art references that are used, in my analysis below, in combination with Lissianski-Patent (e.g., Olson-Paper). Further, Lissianski-Patent was not relied upon by the USPTO examiner in rejecting any claims of the Challenged Patent, or even discussed during prosecution of the Challenged Patent.

2. Overview of the Disclosure of Lissianski

405. Lissianski-Patent describes the use of halides, particularly bromides, for reducing mercury emissions during coal combustion. The abstract of Lissianski-Patent summarizes the process as follows, with the paragraph spacing added by me to divide the steps:

> A method to reduce emissions in flue gas due to combustion of coal in a combustion unit including the steps of:
>
> combusting coal in a primary combustion zone of the combustion unit;
>
> releasing elemental mercury from the combustion into the flue gas;
>
> injecting NH_4C1, NH_4Br, or NH_4I into the flue gas;

oxidizing the elemental mercury with halogen from the additive;

adsorbing the oxidized mercury generated by the combustion of the coal with an adsorbent in the flue gas, and collecting the adsorbent with the oxidized mercury in a combustion waste treatment system.[643]

406. Lissianski-Patent describes that during coal combustion, mercury is emitted in two different states—elemental mercury (Hg^0) and oxidized mercury (Hg^{+2}).[644] Lissianski-Patent further describes in the background section, "Oxidized mercury (Hg^{+2}) is more easily collected by emission control devices than is elemental mercury. Oxidization of mercury is a known technique to capture mercury and remove it from flue gases."[645] Oxidized mercury is more easily removed because it is "easily adsorbed upon high carbon fly ash *or activated carbon.*"[646]

407. Lissianski-Patent improves the mercury capture by supplying a "halogen agent," such as ammonium bromide (NH4Br) "into the flue gas"—"downstream of the primary combustion zone."[647] Figure 3, annotated below, shows a halogen agent (orange) supplied into mercury-containing flue gas (green).[648]

643 Ex. 1036 (Lissianski-Patent) at Abstract.
644 Ex. 1036 (Lissianski-Patent) at 1:22-23.
645 Ex. 1036 (Lissianski-Patent) at 1:24-25.
646 Ex. 1036 (Lissianski-Patent) at 1:35-36 (emphasis added).

647 Ex. 1036 (Lissianski-Patent) at 2:8-10, 2:44-45; *see also* Ex. 1036 (Lissianski-Patent) at claim 1.
648 Ex. 1036 (Lissianski-Patent) at Fig. 3.

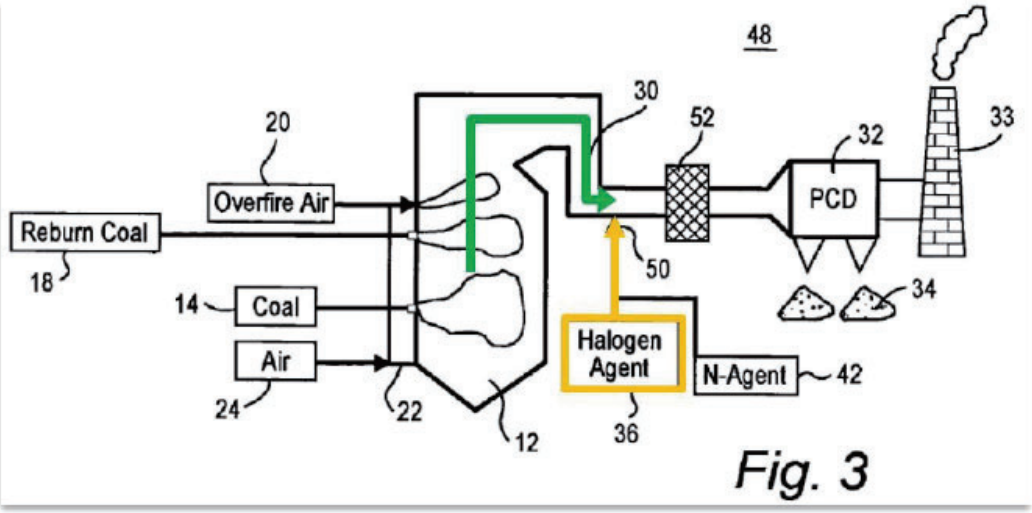


Fig. 3

408. The halogen is provided at "flue gas temperatures of, for example, 1600°F. to 2300°F," and is transported to the flue gas with "air, recycled flue gas, nitrogen or another carrier gas," or in ammonia.[649] The halogen is dispersed into the gaseous phase, especially at the flue-gas temperatures. The "hot flue gas causes the additive to thermally decompose to form … HBr … which results in more significant mercury oxidation. The increase in mercury oxidation allows for improved efficiency of mercury removal by activated carbon (AC) injection."[650] The halogens of Lissianski-Patent also "increase efficiency of NOx reduction,"

[649] Ex. 1036 (Lissianski-Patent) at 4:13-29.
[650] Ex. 1036 (Lissianski-Patent) at 3:45-49; *see also* Ex. 1036 (Lissianski-Patent) at claim 8.

another harmful pollutant, "by reducing oxides of nitrogen to molecular nitrogen."[651]

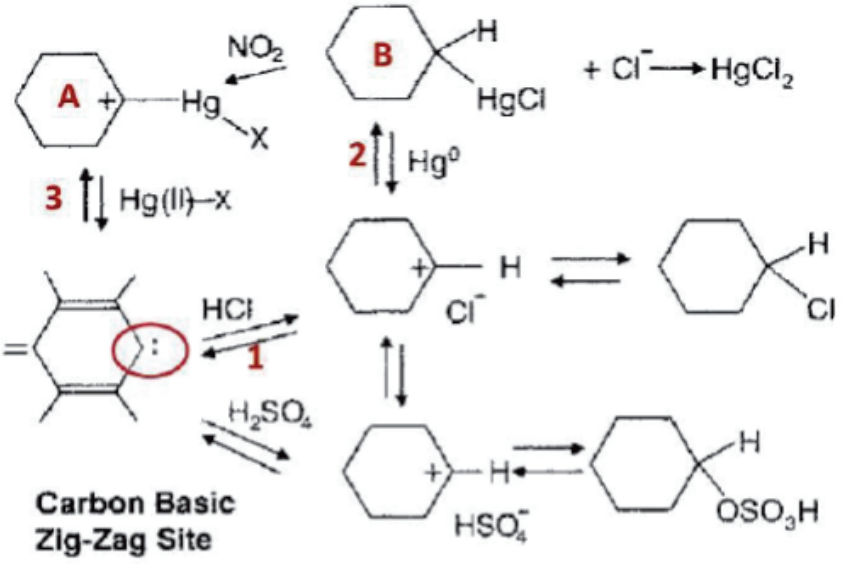


Figure 2. Reaction site model for activated carbon.

Ex[1079]

E. THE GRANITE REFERENCE

409. Ex. 2003 ("Granite") is the reference article authored by Evan J. Granite et al., titled "Novel Sorbents for Mercury Removal from Flue Gas," 39 Ind. Eng. Chem. Res. 1020 (2000).

[651] Ex. 106 (Lissianski-Patent) at 3:23-25, 4:55-59.

1. Prior-Art Status of Granite

410. Granite was published in the journal Industrial & Engineering Chemistry Resarch, which is a peer-reviewed and generally available journal of the American Chemical Society. Granite's publication date is indicated at March 10, 2020.

2. Overview of the Disclosure of Granite

411. Granite gives an overview of the state of art of the use of various sorbents to remove mercury from the emissions of coal burning utilities: "Dry sorbents have the potential to remove both elemental and oxidized forms of mercury. Activated carbons have been successfully applied for the control of mercury emissions from incinerators."[652] Granite also discusses various chemicals that were known or suspected to promote enhanced mercury removal for sorbents such as activated carbon.[653] Activated carbon is the most discussed sorbent in the Granite reference.[654] Granite also reports experimental results for a sorbent screening unit in order to evaluate the capacity of various sorbents for mercury capture.[655] The goal of the experiments was to simulate capture of mercury from the flue gases of full scale commercial systems.[656]

[652] Granite at 1020.
[653] Granite at 1020.
[654] Granite at 1025.
[655] Granite at 1021.
[656] Granite at 1024-25.

M. THE OLSON-646 REFERENCE

412. Exhibit 1014 ("Olson-646") is U.S. Patent Application Publication No. 2006/0048646, which names Edwin S. Olson, Michael J. Holmes, and John H. Pavlish as co-inventors and was assigned to Energy & Environmental Research Center Foundation. Olson-646 is entitled "Sorbents for the Oxidation and Removal of Mercury."[657]

1. Prior-Art Status of the Olson-646 Reference

413. I have been informed that Olson-646 was published by the USPTO on march 9, 2006 as U.S. Patent Pub. No. 2006/0048646 from U.S. Patent Application No. 11/209,163. As described above, the Challenged Claims of the '114 Patent do not have priority support to the earlier-filed applications. Accordingly, I understand that Olson-646 qualifies as prior art.

2. Overview of the Disclosure of Olson-646

414. Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[658]

[657] Ex. 1014 (Olson-646).
[658] Ex. 1014 (Olson-646) at ¶ [0054], Figure 2.

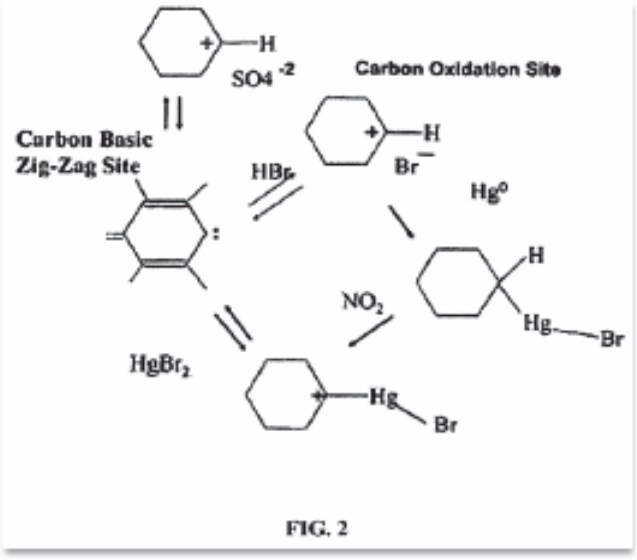


FIG. 2

415. Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[659] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[660] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[661] Figure 2 of Olson-646, reproduced above, shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury.[662]

[659] Ex. 1014 (Olson-646) at ¶ [0054].
[660] Ex. 1014 (Olson-646) at ¶ [0054].
[661] Ex. 1014 (Olson-646) at ¶ [0054].
[662] Ex. 1014 (Olson-646) at Figure 2.

416. Olson-646 provides implementation details regarding promoting activated carbon with a bromine-containing reagent to form promoted activated

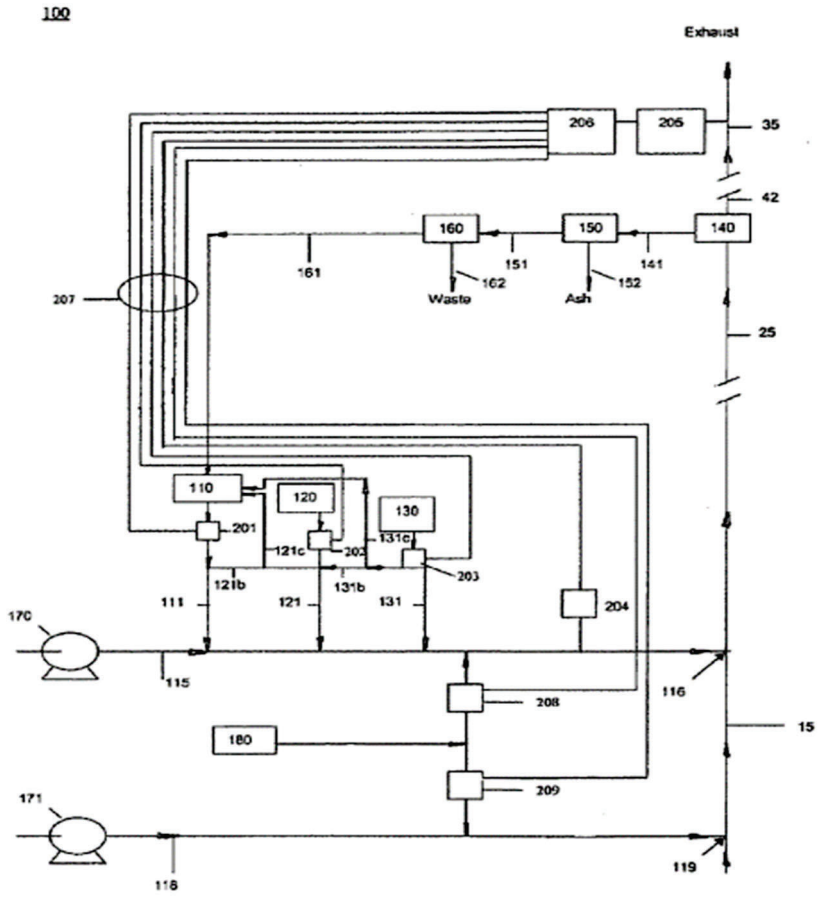


FIG. 3

carbon, and then injecting the promoted activated carbon in the mercury-containing (flue) gas stream in Figure 3, reproduced below.[663]

Figure 3 of Olson-646 shows a schematic of "mercury control system 100 comprising preparation of promoted carbon sorbents, and flue gas mercury reduction, in accordance with preferred embodiments of the present invention."[664]

[663] Ex. 1014 (Olson-646) at Figure 3.
[664] Ex. 1014 (Olson-646) at ¶ [0056].

417. Olson-646 explains that Figure 3 shows a "base activated carbon reservoir 110, an optional halogen/halide promoter reservoir 120, an optional secondary component reservoir 130, and an optional alkali component reservoir 180, each of which with corresponding flow control device(s) 201, 202, 203, and 208/209, respectively."[665] Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[666]

XVII. MOTIVATIONS TO COMBINE

A. SJOSTROM WITH ECKBERG AND OLSON-646

418. A person of skill in the art would have been motivated to combine Sjostrom and Eckberg, and have a reasonable expectation of success in applying the teachings of Eckberg to Sjostrom, because both references teach the use of bromine-based halogens in conjunction with activated carbon to improve mercury removal from flue gas emission leaving coal-fired power plants. The title of Sjostrom is "Full Scale Evaluations of Mercury Control Technologies with PRB Coals."[667] Sjostrom provides an overall process schematic showing the injection of halogens and activated-carbon sorbents for mercury removal in coal-fired flue gas.[668] Sjostrom discusses that activated carbon was a well-known sorbent for mercury control and discloses suitable ranges for sorbent injection rate.[669] Sjostrom also teaches injection

[665] Ex. 1014 (Olson-646) at ¶ [0056].
[666] Ex. 1014 (Olson-646) at ¶ [0061].
[667] Ex. 1010 (Sjostrom) at 1.
[668] Ex. 1010 (Sjostrom) at 4.
[669] Ex. 1 O IO (Sjostrom) at 10, 11, 16.

of bromine onto coal, into the combustion chamber, or concurrently with the sorbent, but does not expressly describe the form of bromine to use or the quantity of bromine to add.[670]

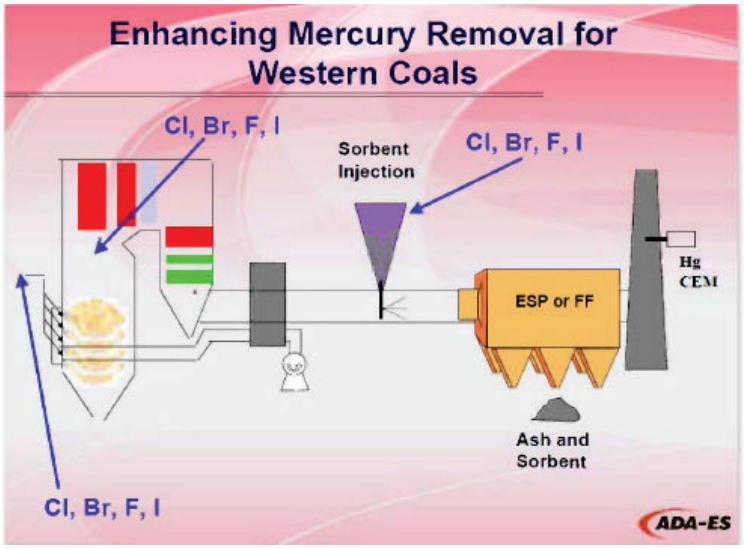
419. A POSITA would have been motivated to look to the teachings of Eckberg to provide these implementation details, for example, to be able to implement the system described in Sjostrom. The title of Eckberg is "Mercury Control Evaluation of Halogen Injection into a Texas Lignite-Fired Boiler.[671] Eckberg includes a similar process schematic as Sjostrom that shows injection of halogens into a coal-fired boiler for mercury removal.[672] Eckberg tells a POSITA the type of bromine to be used (calcium bromide), the bromine: coal ratio (0.09%), the bromine liquid feed rate (1.6 gpm), and the estimated gas concentration of HBr in the flue gas (50 ppm).[673]

420. A POSITA would be further motivated to combine the references, and have a reasonable expectation of success, because both references were presented at the 2005 EUEC.[674] In fact, both references were originally presented one after the other during the same "A3" session of the 2005 EUEC on Tuesday, January 25, 2005 from 7:30-9:30 am.[675] Namely, Sjostrom was presented in the A3b slot and Eckberg

[670] Ex. 1010 (Sjostrom) at 4.
[671] Ex. 1011 (Eckberg) at 1.
[672] Ex. 1011 (Eckberg) at 5.
[673] Ex. 1011 (Eckberg) at 3, 9, 14, 15.
[674] Ex. 1030 (EUEC Handout) at 23.
[675] Ex. 1030 (EUEC Handout) at 23.

was presented in the A3c slot.[676] Further, both presentations included a common author—Dr. Ramsay Chang, Ph.D.—and shared a common partner, namely EPRI.[677] Thus, a POSITA attending the conference, or reading the materials after the POSITA received the CD mailed by the EUEC, would have understood that the two presentations included related material and would have benefited one another. Moreover, a POSITA would have been likely to see the material in Sjostrom and Eckberg sequentially, thereby increasing the likelihood that a POSITA would have viewed the two references as complementing each other.

421. As noted above, Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, addition of halogens, and combining sorbents with halogens, as detailed below.[678]



[676] Ex. 1030 (EUEC Handout) at 23.
[677] Ex. 1030 (EUEC Handout) at 23.
[678] Ex. 1010 (Sjostrom) at 4.

Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[679] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected within the process in multiple locations.[680] A POSITA would have understood that the "Cl, Br, F, I" of Sjostrom referred generally to the addition of chlorine, bromine, fluorine, and iodine in any form, rather than the pure elemental form alone. In fact, a POSITA would have understood that the pure elemental forms of these elements are not readily obtainable and would not have been strong candidates for injection in the system of Sjostrom. Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)" achieved throughout the testing performed on coal flue gas.[681] Sjostrom also shows activated-carbon sorbents that are treated with halogen additives are more effective at removing mercury from flue gas than untreated sorbent alone.[682]

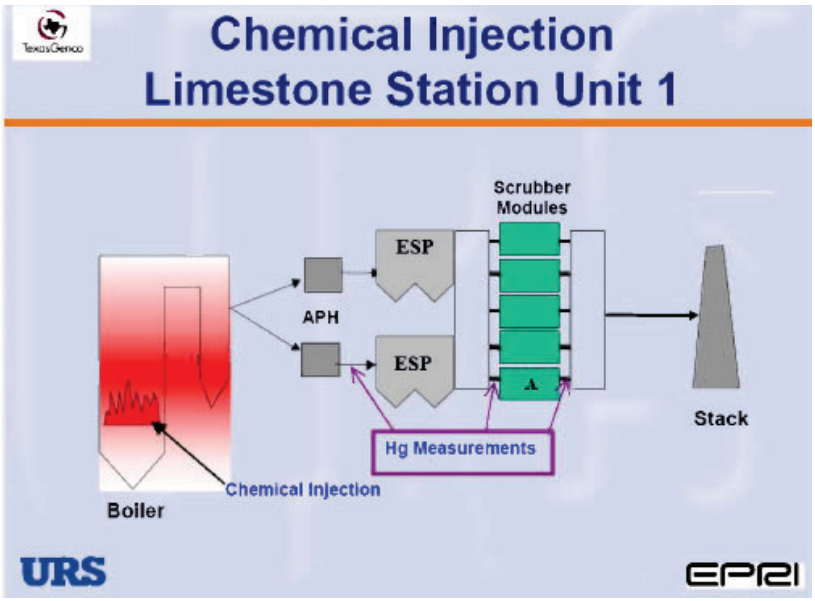
422. Although Sjostrom provides overall process descriptions and sorbent injection rates, and also diagrams and highlights the improved results of halogens used in combination with activated-carbon sorbents, Sjostrom does not expressly describe the specific chemicals used for the halogen injection or the specific injection rates. In particular, Sjostrom describes adding halogens (including bromine) to the coal, but does not identify the specific halogen reagent or its feed

[679] Ex. 1010 (Sjostrom) at 10-11.
[680] Ex. 1010 (Sjostrom) at 4.
[681] Ex. 1010 (Sjostrom) at 8, 15-17, 20, and 21.
[682] Ex. 1010 (Sjostrom) at 16.

rate. A person of skill in the art would have looked to the Eckberg reference to further tune implementation of a system like that of Sjostrom because it expressly describes the chemical formula of the halogen (adding calcium bromide, CaBr2, onto the coal or into the combustion chamber and having it react to provide HBr in the flue gas), as well as the flow rate of calcium bromide, the resulting bromine: coal ratio, and the resulting concentration of HBr in the flue gas in such a system. Specifically, Eckberg teaches injection of "CaCl2 (25 wt%)" or "CaBr2 (52 wt%)" into the combustion chamber.[683] As a result of this injection, the bromine is provided at a 0.09 weight % (relative to coal), which dissociates and further reacts in the gas phase to provide 50 ppm HBr in the flue gas.[684]

423. Like Sjostrom, Eckberg also teaches enhancing mercury removal through halogen injection into a boiler. Eckberg describes several testing objectives including "[i]ncreas[ing] mercury oxidation in flue gas derived from Texas lignite" and "[e]nhanc[ing] mercury removal across wet scrubbers."[685] As shown in the figure below, and similar to Sjostrom, Eckberg describes testing the mercury removal effects of halogen injection directly into a coal-fired boiler.[686]

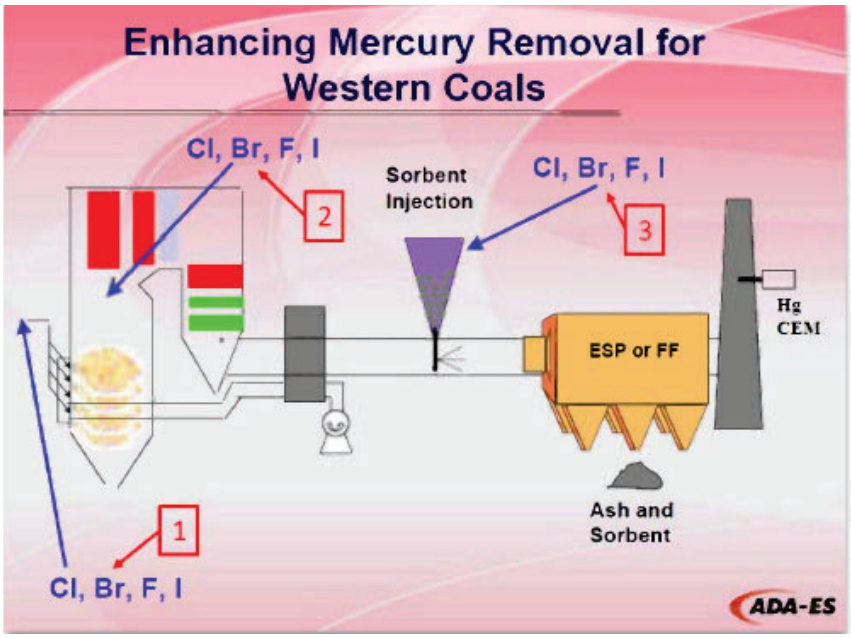
[683] Ex. 1011 (Eckberg) at 9.
[684] Ex. 1011 (Eckberg) at 9.
[685] Ex. 1011 (Eckberg) at 3.
[686] Ex. 1011 (Eckberg) at 5.



As discussed below, a POSITA would have been motivated to apply the teachings of Eckberg to Sjostrom because it would have provided well-known chemical substances that could be used as the "Cl" or "Br" identified in the figures of Sjostrom.

424. Eckberg described a similar location as Sjostrom for adding halogens halogen into the overall system, namely directly within the boiler. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen addition, and a combination of the two.[687] Specifically, the annotated figure below shows that Sjostrom teaches adding halogens in at least three locations.[688]

[687] Ex. 1010 (Sjostrom) at 4.
[688] Ex. 1010 (Sjostrom) at 4 (annotations in red).



Addition Location 2 of Sjostrom teaches Br into the boiler,[689] the same location as in Eckberg.

425. A POSITA would have a reasonable expectation of success applying Eckberg's teachings regarding the specific type, concentration, and rate of addition of bromine-containing species to the overall system of Sjostrom to create an operational system, because in combining Sjostrom with Eckberg, no modifications would need to be made to the overall process equipment, operating conditions, or activated-carbon sorbent used in Sjostrom. Eckberg describes a nearly identical system operating at similar conditions. Thus, a POSITA would have had a reasonable expectation of success in using the salt solutions of Eckberg in the system of Sjostrom.

[689] Ex. 1010 (Sjostrom) at 4 (annotations in red).

426. A POSITA would have seen the overall process goals and schematics and would have understood that applying the specific teachings of Eckberg to implement the system of Sjostrom would have been obvious to try because of the overall similarities between the references. Both references apply halogen additions to coal-plants to remove mercury from flue gas.[690] Both references include similar surrounding equipment, such as boilers, air pre-heaters, and ESPs or other particulate matter control devices.[691]

427. Similarly, a person of ordinary skill in the art would have looked to Olson-646 to provide certain implementational details regarding the system disclosed in Sjostrom, such as which specific bromine-containing ("Br") species to use and the ratios of bromine promoter to activated-carbon sorbent. A person of skill in the art would have been motivated to combine Sjostrom and Olson-646, with or without Eckberg, and have a reasonable expectation of success in applying the teachings of Olson-646 to Sjostrom, because these references teach the use of halogens and activated-carbon sorbents to improve mercury removal from flue gas emission leaving coal-fired power plants. The title of Sjostrom is "Full Scale Evaluations of Mercury Control Technologies with PRE Coals."[692] Similarly, the title of Olson is "Sorbents for the Oxidation and Removal of Mercury."[693]

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690 Ex. 1010 (Sjostrom) at 4; Ex. 1011 (Eckberg) at 2, 9.
691 Ex. 1010 (Sjostrom) at 4; Ex. 1011 (Eckberg) at 5.
692 Ex. 1010 (Sjostrom) at 1 (Title).
693 Ex. 1014 (Olson-646) at 1 (Title).

428. Sjostrom teaches separating mercury from a mercury-containing gas by adsorbing the mercury onto activated carbon, and then separating the mercury/sorbent complex. The title of Sjostrom is "Full Scale Evaluations of ***Mercury Control Technologies*** with PRB Coals."[694] Sjostrom described testing mercury removal from flue gas of coal-fired power plants using sorbent injection, halogen injection, and both sorbent and halogen injection as detailed in the Sjostrom figure above.[695]

429. Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[696] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected within the process in multiple locations.[697] Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)" achieved throughout the testing performed on coal flue gas.[698] Sjostrom also shows activated-carbon sorbents that are treated with halogen additives are more effective at removing mercury from flue gas than untreated sorbent alone.[699]

430. Sjostrom provides overall process descriptions and diagrams and highlights the improved results of halogens used in combination with activated-

694 Ex. 1010 (Sjostrom) at 1 (emphasis added).
695 Ex. 1010 (Sjostrom) at 4.
696 Ex. 1010 (Sjostrom) at 10-11.
697 Ex. 1010 (Sjostrom) at 4.
698 Ex. 1010 (Sjostrom) at 8, 15-17, 20, and 21.
699 Ex. 1010 (Sjostrom) at 16.

carbon sorbents. To the extent that Sjostrom does not expressly describe some implementation details associated with the chemicals and reactions taking place when these chemicals are injected as described in Sjostrom, a person of skill in the art would have looked to the Olson-646 reference for guidance on how to select the implementation details. Like Sjostrom, Olson-646 describes using a conventional halogen (bromine) in a conventional way (as a promoter) to increase the effectiveness of a conventional sorbent (activated carbon) to capture mercury from coal flue gas. Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[700] A person of ordinary skill in the art would also look to Olson-646 for additional discussion of underlying chemistry already theorized to take place by the processes disclosed in Sjostrom.

431. Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[701]

[700] Ex. 1014 (Olson-646) at ¶ [0066].
[701] Ex. 1014 (Olson-646) at ¶ [0054], Figure 2.

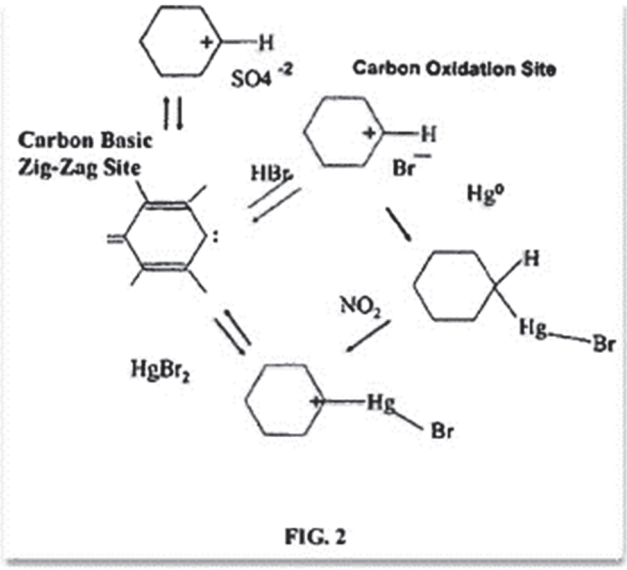


FIG. 2

Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[702] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[703] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[704] Figure 2 of Olson-646 shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury. Thus, a POSITA would have been motivated to apply the teachings of Olson-646 to Sjostrom because it would have provided well-known details regarding the chemicals and associated reactions that would have been used in the system of Sjostrom for mercury control from

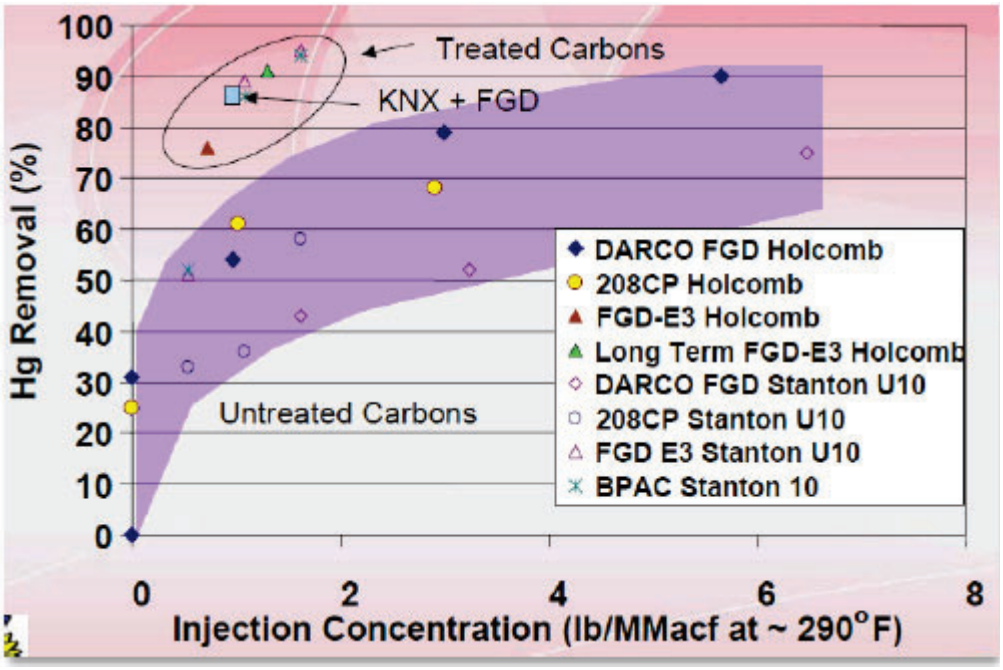
[702] Ex. 1014 (Olson-646) at ¶ [0054].
[703] Ex. 1014 (Olson-646) at ¶ [0054].
[704] Ex. 1014 (Olson-646) at ¶ [0054].

coal flue gas. Specifically, a POSITA would have been motivated to use the "HBr or Br2" of Olson-646 as the "Br" injection of Sjostrom.

432. A person of skill in the art would have been further motivated to combine the references to understand the chemical properties of activated carbon and halogen-promoted activated carbon, and have had a reasonable expectation of success in doing so, because both references discuss the same halogen promoters (e.g., "Br" in Sjostrom and "HBr or Br_2" in Olson-646) and mercury sorbents (activated carbon). In fact, both references teach the same supplier (Norit) and specific brand name (Darco FGD®) of powdered activated carbon (PAC). Sjostrom describes mercury removal testing performed using "DARCO FGD" sorbent.[705] Likewise, Olson-646 teaches the use of "powdered activated carbon" such as "NORIT Darco FGD."[706]

433. A POSITA would have been additionally motivated to apply the teachings of Olson, and have had a reasonable expectation of success in doing so, because, both references teach using the same chemicals to achieve the same results. For example, the below figure of Sjostrom shows removing 70 wt % or more of mercury from the mercury-containing coal flue gas using halogen treated activated carbons (KNX + FGD).[707]

[705] Ex. 1010 (Sjostrom) at 15, 16.
[706] Ex. 1014 (Olson-646) at ¶ [0095].
[707] Ex. 1010 (Sjostrom) at 16.



Likewise, Olson-646 explains that "a method is provided for reducing mercury in flue gas comprising providing a sorbent, injecting the sorbent into a mercury-containing flue gas stream, collecting greater than 70 wt % of the mercury in the flue gas on the sorbent to produce a cleaned flue gas, and substantially recovering the sorbent from the cleaned flue gas."[708]

434. Looking to the implementation details provided in the Olson-646 reference, to understand the chemicals and reactions taking place when these chemicals in Sjostrom, would have been nothing more than using known results to improve one process in a known way to improve a similar process. Further, the implementation details provided in Olson-646 are simply proposed workable ranges (such as concentration ratios), which were conventional and known in the art, and

[708] Ex. 1014 (Olson-646) at ¶ [0022].

would have been selected, or at least tried, as part of routine process optimization by a POSITA applying the teachings of Sjostrom.

B. DOWNS-BOILER WITH EPA-PROPOSAL AND NELSON

435. A POSITA would have looked to the EPA-Proposal to identify a target for needed mercury removal of 70% or more of mercury from the mercury-containing flue gas. Downs-Boiler discusses EPA standards regulating mercury emissions from coal-fired plants.[709] The EPA-Proposal discusses several ways to reduce mercury emissions to a desired level, including by injecting activated-carbon sorbent material (bare or impregnated with halides), and controlling the sorbent injection rate to achieve the desired level of mercury removal.

436. As I describe in the State of the Art section,[710] a person of skill in the art would have been motivated at least by January 2004 to operate their power plants in a manner compliant with the EPA proposed rules in order to avoid eventual regulatory fines that would be imposed for violating those limits, and would have been motivated to try remediation methods described by the EPA. On December 15, 2003, the EPA signed proposed rules and published them on January 30, 2004 in the Federal Register.[711] The EPA further explained that the "rules would significantly reduce emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and

[709] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) irj [002].
[710] State of the Art, §§ VIII.D — VIII.F.
[711] Ex. 1009 (EPA-Proposal) at 4652 (Cover).

mercury from power plants," and explained that publication "in the Federal Register marks the beginning of a 60 day comment period" that included public hearings.[712] The proposed rules stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018."[713] The EPA again announced this "70 percent" reduction on February 24, 2004, in mercury emissions when it further sought public comment.[714] Accordingly, as of January 2004, if not earlier, the EPA put the power-generation industry on notice that upcoming regulations would require a 70% reduction in mercury emissions, and plant operators were motivated to identify processes that would achieve those limits.

437. A POSITA would have had a reasonable expectation of success in combining Downs-Boiler with the EPA-Proposal because both references address injection of activated carbon for purposes of removing mercury from a flue gas. As discussed above in section XVI.K, Downs-Boiler discloses injecting an activated carbon into the mercury-containing flue gas, such as upstream of a particulate collector. Likewise, the EPA-Proposal describes "sorbent injection" to introduce sorbent into the flue gas. "Sorbents can be introduced by two basic methods: by channeling flue gas through a bed of sorbent or by direct sorbent injection."[715] With sorbent injection, "after sorbent is introduced into the flue gas, it adsorbs Hg and

[712] Ex. 1057 (1/29/2004 EPA Press Release).
[713] Ex. 1009 (EPA-Proposal) at 4698.
[714] Ex. 1058 (2/24/2004 EPA Press Release).
[715] Ex. 1009 (EPA-Proposal) at 4676.

other contaminants and is captured downstream in an existing or sorbent-specific PM [(particulate matter)] control device."[716] The EPA specifically mentions "activated carbon" as an example of a sorbent that can be injected into a flue gas.[717]

438. A POSITA would have looked to Nelson to provide certain implementational details regarding the system disclosed in Downs-Boiler, such as the ratios of bromine-containing reagent to sorbent to use. Downs-Boiler describes adding bromine to the coal and to the combustion chamber as a method of increasing the bromine concentration in the mercury-containing flue gas, thus increasing the fraction of oxidized mercury bromide ($HgBr_2$) in the mercury-containing flue gas, and subsequently adsorbing oxidized mercury onto activated carbon in order to separate the mercury and form a cleaned gas. Also, Nelson provides additional detail of the process already taking place in Downs-Boiler, that when bromine adsorbs onto activated carbon, a chemical reaction takes place. Downs-Boiler provides various bromine addition rates in order to remove sufficient mercury to form a cleaned gas.[718] However, Downs-Boiler does not expressly state the injection rate of activated carbon or the ratio of bromine to activated carbon, and Downs-Boiler does not expressly state the location where the downstream injection of activated carbon takes place. In addition to these process parameters being well-known to a POSITA

[716] Ex. 1009 (EPA-Proposal) at 4676.
[717] 727 Ex. 1009 (EPA-Proposal) at 4676.
[718] Ex. 1006 (Downs-Boiler) at Figure 3; Ex. 1007 (Downs-Boiler-Provisional) at Figure 3.

as a matter of routine implementation, a POSITA would also have been motivated to look to Nelson to provide these implementation details. A POSITA would have looked to Nelson for the ratio of bromine to activated carbon able to remove sufficient mercury to meet the regulatory pressures understood in the industry. Nelson describes ranges of bromine:sorbent ratios that are effective in removing both oxidized mercury and elemental mercury.

439. As additional motivation to combine, Downs-Boiler discloses the presence of both elemental and oxidized mercury in the mercury-containing gas noting that "PAC injection removes both oxidized and elemental mercury species, although removal efficiencies are higher for the oxidized form."[719] In order to deal with the challenge of removing elemental mercury, a POSITA would have looked to Nelson which describes the amounts of bromine on activated carbon, such that "the sorbent adsorbs its elemental mercury and oxidized mercury species."[720]

440. A POSITA would have been further motivated to combine Downs-Boiler and Nelson and would have had a reasonable expectation of success in applying the teachings of Nelson to Downs-Boiler, because both references teach the use of bromine (particularly, HBr and/or Br_2) and activated-carbon sorbents to improve mercury removal from flue gas emissions from coal-fired power plants.

[719] Ex. 1006 (Downs-Boiler) ¶ [0004]; Ex. 1007 (Downs-Boiler-Provisional) 4111 [005].
[720] Ex. 1012 (Nelson) at 9:35-37; *see also* 6:26-41.

The title of Downs-Boiler is "Bromine Addition for the Improved Removal of Mercury from Flue Gas,"[721] and the title of Nelson is "Sorbents and Methods for the Removal of Mercury from Combustion Gases."[722]

C. DOWNS-HALOGEN WITH LISSIANSKI AND OR OLSON PAPER

441. A POSITA would have been motivated to combine Downs-Halogenation with the Olson-Paper and also with Lissianski-Patent. Downs-Halogenation describes injecting a bromine-containing promoter (particularly HBr) and activated carbon, such that an in-flight reaction occurs to produce a "stream of dynamically halogenated PAC" *(i.e.,* promoted brominated sorbent).[723] Downs-Halogenation also describes the use of this dynamically halogenated PAC such that it is "injected into the flue gas stream" *(i.e.,* a mercury-containing gas) for subsequent removal of mercury.[724]

442. Lissianski-Patent discloses that some types of coal tend to have "low chlorine (Cl) content" natively, which results "in relatively high levels of elemental mercury in the flue gas from low rank coal."[725] Lissianski-Patent discloses a process for increasing the concentration of halogen-containing promoter (including HBr) in a mercury-containing gas. Lissianski-Patent teaches supplying a halogen upstream

[721] Ex. 1006 (Downs-Boiler) at Title; *see also* Ex. 1007 (Downs-Boiler-Provisional) at Title.
[722] Ex. 1012 (Nelson) at Title.
[723] Ex. 1015 (Downs-Halogenation) at ¶ [0023]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026].
[724] Ex. 1015 (Downs-Halogenation) at ¶ [0023]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026].
[725] Ex. 1036 (Lissianski-Patent) at 1:52-67.

of the activated carbon sorbent, as separate streams, directly into a mercury-containing flue gas. Lissianski-Patent explains injection using "recycled flue gas" as the carrier gas, such as from a bleed line off of the flue gas path, in order to "improve mixing of the [bromine-containing promoter] and flue gas."[726] Lissianski-Patent explains that the formation of HBr in the flue gases "results in more significant mercury oxidation. The increase in mercury oxidation allows for improved efficiency of mercury removal by activated carbon (AC) injection."[727]

443. A POSITA would have been motivated, and would have had a reasonable expectation of success, in starting with the disclosure of Downs-Halogenation for preparing a dynamically-halogenated activated carbon by separately injecting a bromine-containing promoter (blue) and activated-carbon sorbent (red) into a transport line (purple), with an in-flight reaction occurring in the transport line. Figure 2 (annotated) of Downs-Halogenation is shown below:[728]

[726] Ex. 1036 (Lissianski-Patent) at 4:20-23; *see also* Ex. 1036 (Lissianski-Patent) at claim 24 ("air, recycled flue gas and nitrogen gas").
727 Ex. 1036 (Lissianski-Patent) at 3:45-48; *see also* Ex. 1036 (Lissianski-Patent) at claim 8.
[728] Ex. 1015 (Downs-Halogenation) at Fig. 2 (annotated); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at Fig. 2.

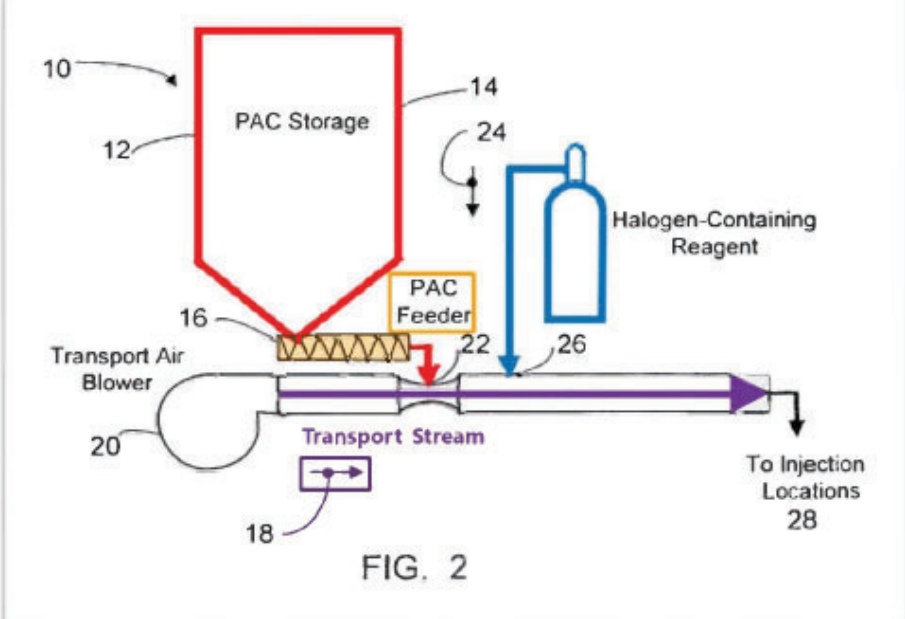
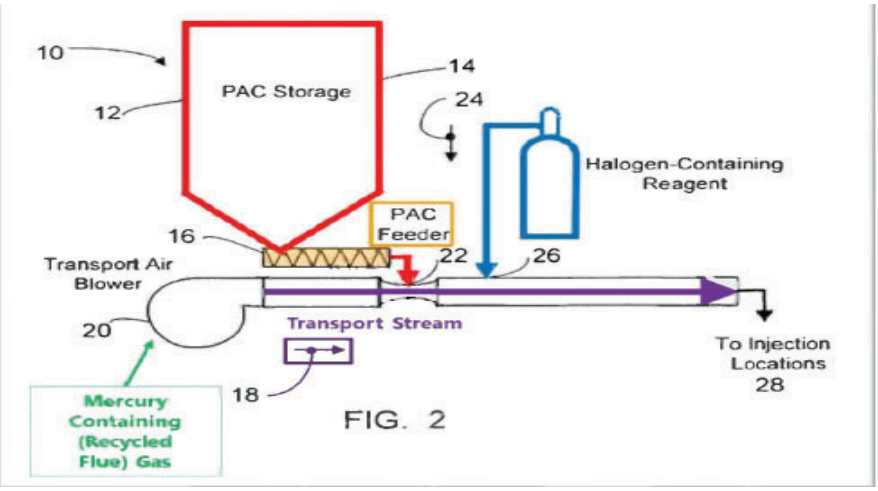


FIG. 2

Based on the teachings of Lissianski-Patent, a POSITA would have been motivated to use a stream of recycled flue gas (below, green) as the medium in which activated-carbon sorbent and halogen-containing reagent undergo an in-flight reaction, and for carrying the entrained dynamically-halogenated activated carbon to the injection location(s) 28 in the main flue gas duct. The combined system would look like the following annotated Fig. 2 of Downs-Halogenation, where the material in green indicates content drawn from Lissianski-Patent:[729]

[729] Ex. 1015 (Downs-Halogenation) at Fig. 2 (annotated); *see also* Ex. 1016 (Downs-Halogenation-Provisional) at Fig. 2.



A POSITA would have been motivated to use the recycled flue gas as the transport gas because Lissianski-Patent specifically discloses using recycled flue gas as one type of transport gas to inject into a flue gas duct.[730]

444. A POSITA would have had a reasonable expectation of success in using recycled flue gas as the medium for in-flight reaction between sorbent and promoter, and to transport the promoted brominated carbon, because Downs-Halogenation teaches flexibility in the means used to convey the dynamically halogenated PAC to the activated carbon. Specifically Downs-Halogenation discloses that, in addition to the use of air as a transport gas, "pneumatic transport conveying system[s], and many other configurations could be used or developed by one of ordinary skill in the art without departing from the scope of the present invention."[731] Lissianski-Patent expressly identifies such pneumatic transport conveying mediums, including: "air,

[730] Ex. 1036 (Lissianski-Patent) at 4:20-23; *see also* Ex. 1036 (Lissianski-Patent) at claim 24 ("air, *recycled flue gas* and nitrogen gas").
[731] Ex. 1015 (Downs-Halogenation) at ¶ [0019]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0022].

recycled flue gas, nitrogen or another carrier gas."[732] For the purposes of the pneumatic transport system disclosed by Downs-Halogenation, each of these would have been understood by POSITA as a mere substitution of one element for another known in the field. A POSITA would have understood that the flue gas could have readily been recycled into the transport line that stages bromination and sorbent injection.[733] Flyash can be avoided either by recycling flue gas from downstream of the particle collection device (either an ESP or FF), or by recycling from upstream of the flyash collectors and removing flyash before the recycle stream reaches the blower in the transport line. In either situation, removing flyash minimizes the potential for scavenging of bromine compounds by alkaline and alkaline earth minerals before they can bind to the sorbent.

445. A POSITA would have been further motivated to combine these references because all three references are from the same field of endeavor, namely, using halogens (promoters) with activated carbon (sorbent) in order to remove mercury from combustion gas streams. The references solve the same problem, increasing the effectiveness of mercury removal. Downs-Halogenation is titled "Dynamic Halogenation of Sorbents for the Removal of Mercury from Flue Gases."[734] Similarly, the title of Olson-Paper is "Chemical Mechanisms in Mercury

[732] Ex. 1036 (Lissianski-Patent) at 4:20-23; see also Ex. 1036 (Lissianski-Patent) at claim 24 ("air, recycled flue gas and nitrogen gas").
[733] See, e.g., State of the Art, above, § VIII.A.91.
[734] Ex. 1015 (Downs-Halogenation) at Title; see also Ex. 1016 (Downs-Halogenation-Provisional) at Title.

Emission Control Technologies."[735] Likewise, the title of Lissianski-Patent is "Methods for Removal of Mercury Emissions from Coal Combustion."[736]

446. A POSITA would also have been motivated to combine these references, and would have had a reasonable expectation of success in doing so, because Downs-Halogenation and Lissianski-Patent teach the same sorbent to remove mercury (activated carbon) and each teach improving the effectiveness of that sorbent in removing mercury by using the same promoter (HBr) to improve mercury capture on activated carbon. Downs-Halogenation states:

> A stream of Dynamically Halogenated PAC, prepared by the method of the present invention, was injected into the flue gas stream downstream of the SDA, and upstream of the fabric filter. Hydrogen bromide (HBr) . . . and a commercially-produced PAC were used as the carbonaceous sorbent 14. FIG. 3 illustrates the removal of mercury across the SDA/FF system during operation of the Dynamic Halogenation process with HBr. It can be seen that upon injection of the Dynamically Halogenated PAC, the vapor-phase mercury exiting the system dropped from its initial value of approximately 6 μg/dscm to well below 1 μg/dscm.[737]

447. In a similar manner, Lissianski-Patent states that the same bromine-containing components as Downs-Halogenation, namely HBr, "increases the amount of mercury removal by activated carbon injection."[738]Lissianski-Patent explains that supplying a halogen-containing promoter to the mercury-containing

[735] Ex. 1079 (Olson-Paper) at Title.
[736] Ex. 1036 (Lissianski-Patent) at Title.
[737] Ex. 1015 (Downs-Halogenation) at ¶ [0023]; see also Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0026].
[738] Ex. 1036 (Lissianski-Patent) at 3:20-22, 3:45-47.

assists in oxidizing mercury, thus making it more susceptible for removal on activated carbon or in a wet scrubber.[739]‘ Downs-Halogenation recognizes both of these advantages of mercury appearing in the oxidized from, noting that “[o]xidized mercury . . . is soluble in water, making it amenable to removal in sulfur dioxide scrubbers”[740] and also that “PAC injection removes both oxidized and elemental mercury species, although removal efficiencies are higher for the oxidized form.”[741] Olson-Paper confirms the importance of halogens to the capture of elemental mercury using activated carbon because, “[w]ithout either HCl or NO_2 in the gas stream, the carbon sorbents are ineffective, and immediate breakthrough occurred.”[742]

448. In addition to the use of the recycled flue gas as a transport gas, a POSITA would have been motivated to use the gas-phase “Br” concentration disclosed in Lissianski-Patent for the injection rate of the system of Downs-Halogenation. Downs-Halogenation provides a specific example injection rate for the bromine-containing promoter at 3 ppm of the selected hydrogen bromide.[743] Lissianski-Patent explains that a concentration of 3 ppm “Br” would be acceptable when using a bromine containing promoter *(i.e.,* the same concentration as in

[739] Ex. 1036 (Lissianski-Patent) at 1:35-40, 3:42-50.
[740] Ex. 1015 (Downs-Halogenation) at ¶ [0003]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [004].
[741] Ex. 1015 (Downs-Halogenation) at ¶ [0004]; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [005].
[742] Ex. 1079 (Olson-Paper) at 980.
[743] Ex. 1015 (Downs-Halogenation) at Fig. 3; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at Fig. 3.

Downs-Halogenation [744]) and also would be an acceptable rate for chlorine-containing promoters (like in Olson-Paper [745]). [746] Lissianski-Patent, however, teaches using a lower concentration than 3 ppm as one of the advantages of using a bromine-containing promoter, as compared to a chlorine-containing promoter.[747] According to Lissianski-Patent, "[m]odeling also predicts that bromine is a more effective oxidizing agent than is chlorine. The model predicted that a presence of only 0.3 ppm of bromine in flue gas results almost in the same effect as 3 ppm of chlorine."[748] A POSITA would therefore have been motivated to use a bromine addition rate of 0.3 ppm of bromine in flue gas with the system of Downs-Halogenation that uses the same bromine promoter, namely HBr, and would have had a reasonable expectation of success that the system would perform well given the disclosure in Lissianski-Patent of the efficacy of using 0.3 ppm of bromine. Using the promoter concentration of Lissianski-Patent with the system of Downs-Halogenation in order to further meet the stated goal of Downs-Halogenation to "significantly reduce the cost of mercury removal at coal-fired electric plants."[749]

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744 Ex. 1015 (Downs-Halogenation) at Fig. 3; *see also* Ex. 1016 (Downs-Halogenation-Provisional) at Fig. 3.
745 Ex. 1079 (Olson-Paper) at 980.
746 Ex. 1036 (Lissianski-Patent) at 6:62-64, Fig. 9.
747 Ex. 1036 (Lissianski-Patent) at 6:64-67.
748 Ex. 1036 (Lissianski-Patent) at 6:64-67.
749 Ex. 1015 (Downs-Halogenation) at IT [0020]; Ex. 1016 (Downs-Halogenation-Provisional) at ¶ [0023].

D. LISSIANSKI-PRESENTATION AND OLSON-646

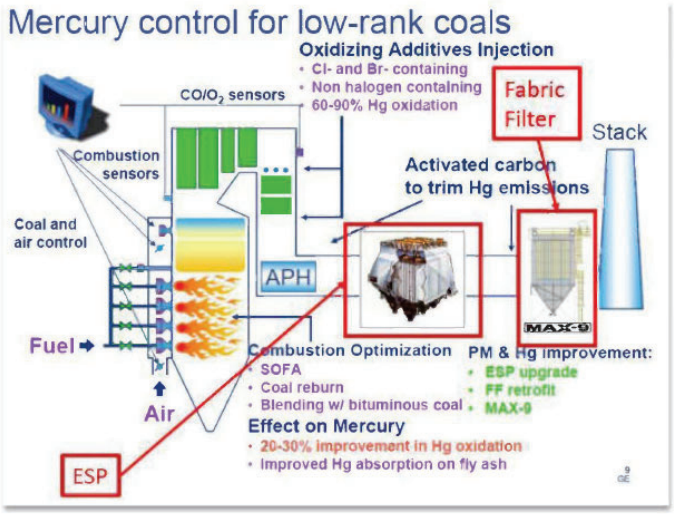
449. A POSITA would have been motivated to combine Lissianski-Presentation and Olson-646 to understand the chemical properties of activated carbon and halogen-promoted activated carbon, and have had a reasonable expectation of success in doing so, because both references discuss the same halogen promoters (e.g., "Br- containing" in Lissianski-Presentation and "gaseous HBr or Br_2" in Olson-646) and mercury sorbents (activated carbon). In fact, both references teach the same supplier (Norit) and specific brand name (Darco FGD®) of powdered activated carbon (PAC). Lissianski-Presentation describes mercury removal testing performed using "Darco FGD" sorbent.[750] Likewise, Olson-646 teaches the use of "powdered activated carbon" such as "NORIT Darco FGD."[751] Olson-646 proposes that the surface structure of activated carbon as used in Lissianski-Presentation, namely that it comprises graphene sheets with carbene edge sites.[752] As discussed above regarding the State of the Art,[753] it was proposed since at least the 1980s that activated carbon (at least in a clean laboratory setting) has graphene sheets having carbene species edge sites. Olson-646 further elaborates on the teachings of Lissianski-Presentation by describing surface compounds formed in the activated

[750] Ex. 2014 (Lissianski-Presentation) at 8.
[751] Ex. 1014 (Olson-646) at ¶ [0095].
[752] Ex. 1014 (Olson-646) at ¶ [0054] ("a carbene species on the edge of the graphene sheet structures of the carbon").
[753] See State of the Art, above, § VIII.C.2.

carbon of Lissianski-Presentation, and proposes a theory for the underlying chemical reaction mechanisms taking place in Lissianski-Presentation.[754] A person of skill in the art would have had a reasonable expectation of success in applying the teachings of Olson-646 to understand the underlying chemistry of the processes described in Lissianski-Presentation because, in combining Lissianski-Presentation with Olson-646, no modifications would need to be made to the chemical reactors, activated carbon sorbent, or type of halogen promoter used in Lissianski-Presentation.

450. A person of skill in the art would have been motivated to combine Lissianski-Presentation and Olson-646 with a reasonable expectation of success in doing so, because both references teach the use of halogens and activated-carbon sorbents to improve mercury removal from flue gas emission leaving coal-fired power plants. The title of Lissianski-Presentation is "Integrated Approach to Multi-Pollutant Control." [755] Specifically, Lissianski-Presentation describes an "[i]ntegrated approach to NOx and mercury control."[756] Similarly, the title of Olson-646 is "Sorbents for the Oxidation and Removal of Mercury."[757] Further, both references discuss the same additional equipment for removing particles of mercury/sorbet composition, such as an ESP and a fabric filter (or baghouse).[758]

[754] Ex. 1014 (Olson-646) at ¶ [0093]; see also Ex. 2014 (Lissianski-Presentation) at 9, 18.
[755] Ex. 2014 (Lissianski-Presentation) at 1.
[756] Ex. 2014 (Lissianski-Presentation) at 2.
[757] Ex. 1014 (Olson-646) at Title.
[758] Ex. 2014 (Lissianski-Presentation) at 9 (annotations in red).

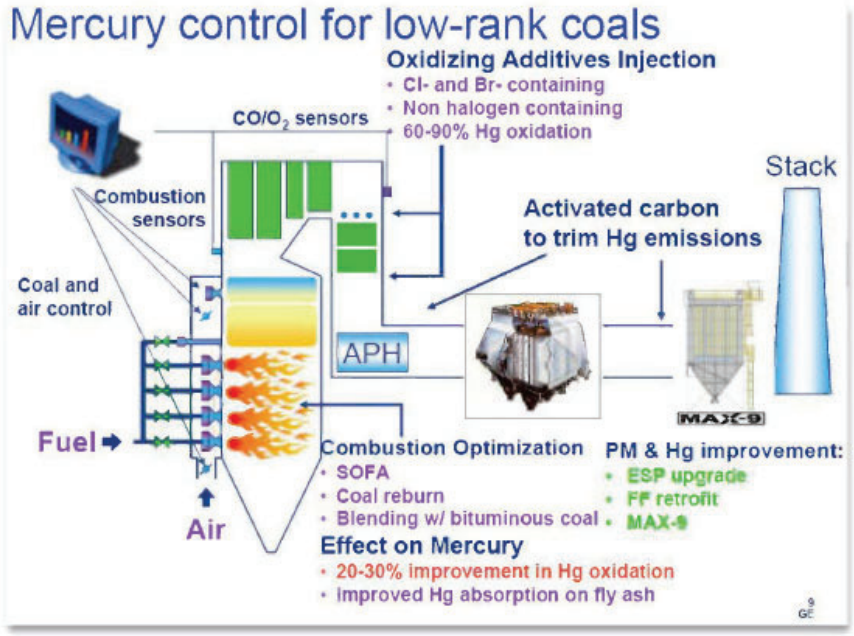


Similarly, Olson-646 discloses the use of particulate control devices including a "baghouse" (e.g., fabric filter) and an "electrostatic precipitator/ESP."[759]Moreover, both references discuss control of NO_x. emissions in addition to mercury control. Lissianski-Presentation describes how halogen injection impacts NOx control.[760] Similarly, Olson-646 also discusses the implications of mercury-removal techniques on NO control.[761]

451. Lissianski-Presentation teaches separating mercury from a mercury-containing gas by adsorbing the mercury onto activated carbon, and then separating the mercury/sorbent chemical composition. Lissianski-Presentation's title is "Integrated Approach to Multi-Pollutant Control." [762] Lissianski-Presentation describes performing mercury removal from flue gas of coal-fired power plants

[759] Ex. 1014 (Olson-646) at ¶ [0110].
[760] Ex. 2014 (Lissianski-Presentation) at 2, 19.
[761] Ex. 1014 (Olson-646) at IN [0075], [0113].
[762] Ex. 2014 (Lissianski-Presentation) at 1.

using halogen-containing promoters (bromine or chlorine) and activated-carbon sorbent injection as detailed below.[763]



As shown in the above figure, Lissianski-Presentation feeds "fuel" (coal) and "air" to a combustion chamber. The combustion generates a mercury-containing gas. Into the mercury-containing gas, Lissianski-Presentation discloses "Oxidizing Additives Injection," which includes halide promoters ("Cl- and Br- containing").[764] Lissianski-Presentation also uses a separate activated-carbon sorbent injection to treat mercury emissions in flue gas.[765] Lissianski-Presentation uses the "Darco" brand of activated carbon.[766]

[763] Ex. 2014 (Lissianski-Presentation) at 9.
[764] Ex. 2014 (Lissianski-Presentation) at 9.
[765] Ex. 2014 (Lissianski-Presentation) at 9.
[766] Ex. 2014 (Lissianski-Presentation) at 8, 18.

452. A POSITA would have been motivated to combine Lissianski-Presentation with Olson-646 to provide certain implementation details for the system in Lissianski-Presentation, such as which specific bromine-containing species to use and the ratios of bromine-containing promoter to activated-carbon sorbent. A POSITA would have also been motivated to combine Lissianski-Presentation with Olson-646 to further understand the surface structure of activated carbon and chemical reactions that take place on that surface, each of which underlies the teachings of Lissianski-Presentation.

453. Like Lissianski-Presentation, Olson-646 describes using a conventional halogen (bromine) in a conventional way (as a promoter) to increase the effectiveness of a conventional sorbent (activated carbon) to capture mercury from coal flue gas. The title of Olson-646 is "Sorbents for the Oxidation and Removal of Mercury."[767] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[768] A POSITA would also look to Olson-646 for additional discussion of underlying chemistry already theorized to take place by the processes disclosed in Lissianski-Presentation.

454. A POSITA would have been motivated to combine the references because both focus on solving the same technical problem, and their solutions both

[767] Ex. 1014 (Olson-646) at Title.
[768] Ex. 1014 (Olson-646) at ¶ [0066].

discuss using the same halogen promoters (e.g., "Br- containing" in Lissianski-Presentation and "gaseous HBr or Br_2" in Olson-646) and mercury sorbents (activated carbon). Olson-646 proposes that the surface structure of activated carbon comprises graphene sheets with carbene edge sites,[769] which had been proposed decades earlier.[770] Olson-646 also identifies surface compounds formed on activated carbon, and proposes a theory for the underlying chemical reaction mechanisms taking place in Lissianski-Presentation. In combining Lissianski-Presentation with Olson-646, no modifications would need to have been made to the chemical reactors, activated carbon sorbent, or type of halogen promoter used in Lissianski-Presentation. A POSITA would have also looked to Olson-646 to provide certain implementational details regarding the system disclosed in Lissianski-Presentation, such as which specific bromine-containing species to use and the ratios of bromine promoter to activated-carbon sorbent.

455. Fig. 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[771]

[769] Ex. 1014 (Olson-646) at ¶ [0054].
[770] See State of the Art, above, § VIII.C.2.
[771] Ex. 1014 (Olson-646) at ¶ [0054], Fig. 2.

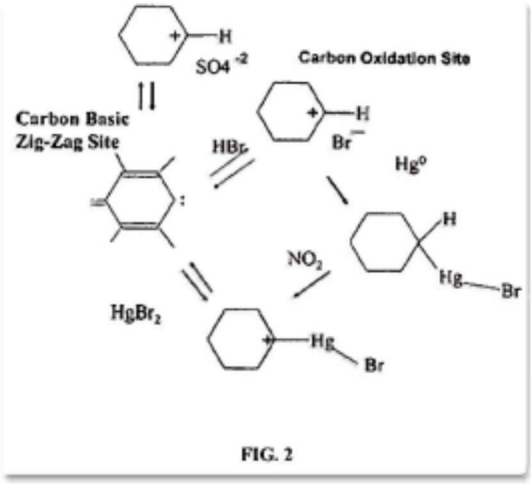


FIG. 2

Olson-646 proposes that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[772] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[773] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[774] Fig. 2 of Olson-646 discloses a complex that includes the activated-carbon sorbent, the element bromine, and the element mercury. Thus, a POSITA would have been motivated to apply the teachings of Olson-646 to Lissianski-Presentation because it would have provided details regarding the well-known chemicals and proposed reaction mechanisms underlying the system of Lissianski-Presentation. Specifically, a POSITA would

772 Ex. 1014 (Olson-646) at ¶ [0054].
773 Ex. 1014 (Olson-646) at ¶ [0054].
774 Ex. 1014 (Olson-646) at ¶ [0054].

have been motivated to use the "HBr or Br_2" of Olson-646 as the bromine injection of Lissianski-Presentation.

456. Looking to the implementation details provided in the Olson-646 reference, to understand the chemicals to use (e.g., use HBr or Br_2 as the "Br-containing" species of Lissianski-Presentation, or the quantities to inject) in Lissianski-Presentation would have been nothing more than using known results to improve one process to achieve the same goal of reducing mercury emissions in coal-fired power plants. Further, the implementation details provided in Olson-646 are simply proposed workable ranges (such as concentration ratios), which were conventional and known in the art, and would have been selected, or at least tried, as part of routine process optimization by a POSITA applying the teachings of Lissianski-Presentation.

E. VOSTEEN AND GRANITE

457. A person of ordinary skill in the art would have looked to Granite for practical applications of the discovery disclosed in Vosteen relating to the use of bromine species added to the coal or combustor to improve the uptake of mercury on activated carbon sorbents. Vosteen describes adding bromine to the coal and to the combustion chamber as a method of increasing the bromine concentration in the mercury-containing flue gas, and then adsorbing oxidized mercuric bromide ($HgBr_2$) onto activated carbon in order to separate the mercury to form a cleaned

gas. Granite discusses the need for promoters such as halogen compounds to address some of the "problems associated with the use of activated carbons for mercury removal from flue gas."[775] Vosteen describes the desired concentration of bromine in the mercury-containing gas in order to achieve near-complete oxidation of mercury,[776] and also describes the bromine to mercury ratio in the mercury-containing gas.[777] However, Vosteen does not expressly state the injection rate of activated carbon or the ratio of bromine to activated carbon, and Vosteen does not expressly state where downstream of the combustion chamber the injection of activated carbon takes place. In addition to these process parameters being well-known to a person of skill in the art as a matter of routine implementation, a person of skill in the art would also have been motivated to look to Granite's disclosure of activated carbon injection systems.

458. A person of skill in the art would have been further motivated to combine Vosteen and Granite, and have a reasonable expectation of success in applying the teachings of Vosteen to Granite, because both references teach the use of promoters and activated-carbon sorbents to improve mercury removal from flue gas emission leaving coal-fired power plants. The title of Vosteen is "Process for

[775] Granite at 1020.
[776] Ex. 1008 (Vosteen) at Figure 6, 10:7-61.
[777] Ex. 1008 (Vosteen) at Claim 6, 10:26-45.

Removing Mercury from Flue Gases," and the title of Granite is "Novel Sorbents for Mercury Removal from Flue Gas."

459. As additional motivation to combine, Granite is exploring effective promoters for activated carbon sorbents, and Vosteen offers a simple and straightforward teaching of bromine species used in conjunction with activated carbon. Vosteen explains that there are no special precautions or locations necessary to use its inventive promoters. A person of skill in the art would have had a reasonable expectation of success in applying the teachings of Vosteen to the typical "coal-fired utilit[ies]" that are of interest to Granite[778] because, in combining Vosteen with Granite, no modifications would need to be have been made to the process conditions, chemical reactors, or activated-carbon sorbent.

F. NELSON WITH OLSON-PAPER AND LISSIANSKI-PATENT

460. Nelson describes improving the effectiveness of mercury capture by promoting activated carbon (sorbent) with a halogen (bromine) gas, such that "a relatively large quantity of the bromine reacts with the carbon, forming surface compounds on the large-surface area of the carbon." Both "elemental mercury and oxidized mercury species" in the flue gas then "react with at least one form of the bromine-carbon surface compounds that were created and are held fast."[779] Nelson further describes that upon "expos[ure] to a bromine-containing treatment gas," the

[778] Granite at 1024.
[779] Ex. 1012 (Nelson) at 6:26-34.

activated carbon "produc[es] surface complexes that are particularly reactive to gaseous mercury species."[780] Although Nelson provides process recipes for promoting activated carbon with bromine, and although Nelson describes that bromine-containing promoters chemically react to form surface compounds with the promoted activated carbon that are particularly reactive towards mercury, Nelson does not expressly describe the details of the surface structure of activated carbon and the "surface complexes" and reaction mechanisms that take place.

461. A person of skill in the art would have been motivated to combine with Olson-Paper, which proposes the surface structure of activated carbon and chemical reactions that take place on that surface, each of which underlies the teachings of Nelson. For example, Olson-Paper expressly discloses that the structure of the activated carbon used in Nelson (Norit Darco FGD®) comprises graphene sheets with carbene edge sites.[781] Olson-Paper further elaborates on the teachings of Nelson by describing a chemical-reaction mechanism by which a carbene species on activated carbon reacts with halogens to form a carbocation and halide anion. A person of skill in the art would have had a reasonable expectation of success in applying the teachings of Olson-Paper to understand the underlying chemistry of the processes described in Nelson because, in combining Nelson with Olson-Paper, no

[780] Ex. 1012 (Nelson) at 6:5-9.
[781] Ex. 1019 (Olson-Paper) at 979 (Abstract), 982.

modifications would need to be have been made to the process conditions, chemical reactors, activated-carbon sorbent, or halogen promoter used in Nelson. Olson-Paper is simply describing chemical reaction mechanisms proposed to take place when performing processes disclosed in Nelson.

462. A person of skill in the art would have been motivated to combine Nelson and Olson-Paper, and would have had a reasonable expectation of success in applying the teachings of Olson-Paper to Nelson, because both references teach the use of halogens to improve the effectiveness of activated carbon in removing mercury. Nelson "relates to the removal of mercury from combustion gas streams and more specifically to the use of halogenated carbon materials to reduce the emissions of mercury from coal-fired plants."[782] Similarly, the title of Olson-Paper is "Chemical mechanisms in mercury emission control technologies."[783]

463. A person of skill in the art would have been further motivated to combine the references to understand the chemical properties of activated carbon and halogen-promoted activated carbon, and have had a reasonable expectation of success in doing so, because both references teach the same supplier (Norit) and the same specific brand name (Darco FGD®) of powdered activated carbon (PAC). Nelson explains: "Norit's Darco FGD® is a common PAC frequently used by other

[782] Ex. 1012 (Nelson) at 1:25-28.
[783] Ex. 1019 (Olson-Paper) at Title.

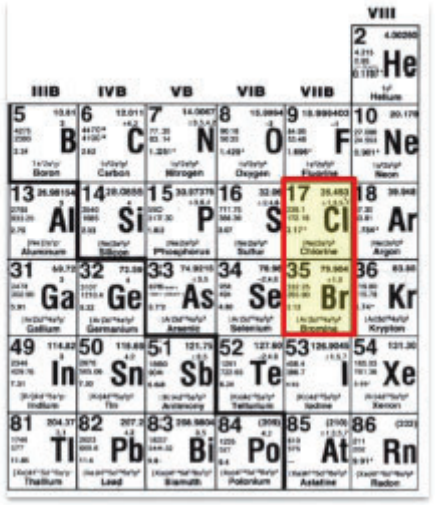
researchers as a comparative yardstick."[784] Indeed, Nelson references this specific type of PAC (powdered activated carbon) in each of the examples and in several figures. Likewise, Olson-Paper teaches the surface structure and chemical mechanisms involved for reactions on the same activated carbon: "Norit FGD."[785]

464. A POSITA would have been additionally motivated to look to the teachings of Olson-Paper, and would have had a reasonable expectation of success in applying those teachings, because a POSITA would have understood the applicability of chloride-containing chemical reactions in activated carbon (as in Olson-Paper) to bromide-containing chemical reactions in activated carbon (as in Nelson). Nelson provides such a teaching because Nelson also discloses embodiments applying chlorine to activated carbon. Nelson teaches that exposing activated carbon to chlorine gas improved the effectiveness of capturing mercury, albeit to a lesser extent than bromine.[786] "The sample that had been exposed to gaseous chlorine, C12(g), exhibited some improvement in mercury removal performance relative to the plain, untreated PAC."[787]

465. In trying to understand the chemical reactions between bromine, activated carbon and mercury, a POSITA would have been motivated to supplement the teachings of Nelson with references describing promoting activated carbon using

[784] Ex. 1012 (Nelson) at 11:17-19.
[785] Ex. 1019 (Olson-Paper) at 981.
[786] Ex. 1012 (Nelson) at Fig. 14, 12:15-19.
[787] Ex. 1012 (Nelson) at 12:28-30, Fig. 11.

chlorine, as in Olson-Paper. Indeed, as I describe in the State of the Art section,[788] it was well-known that bromine and chlorine have similar chemical properties and undergo similar chemical reactions, as the two are in the same group and adjacent to one another in the periodic table of elements.[789]



466. As I also describe, once the superior performance of PACs with appreciable chlorine was demonstrated (as compared to untreated PAC), a person of skill in the art would have realized that other halogens would exhibit the same or, likely, an even greater advantage.[790] There were a limited number of halogens that could be practically used—chlorine, bromine, and iodine—such that a person of skill in the art would have known, and would have been motivated to try, other forms of halogens for mercury removal, beyond chlorine. Nelson further narrows the choices

[788] *See* State of the Art, above, § VIII.A.2, VIII.A.3, VIII.A.7.
[789] Ex. 1027 (Steam) at exhibit page 239.
[790] *See* State of the Art, above, § VIII.C.3, VIII.G.2.

to chlorine and bromine because both "chlorine and bromine … chemically react with strongly-held carbon surface compounds" and desorb less from the activated carbon.[791] Accordingly, a POSITA reviewing Nelson and trying to understand the surface chemistry would have focused on the reactions of activated carbon with bromine or chlorine. Looking to the chemical reaction mechanisms of chlorine-containing compounds, as disclosed in the Olson-Paper, to understand the chemical reaction mechanisms involving bromine, would have been nothing more than seeking additional information regarding the chemical-reaction mechanisms already theorized to take place in Nelson. No modifications would need to have been made to the processes of Nelson.

467. A POSITA would additionally have been motivated to combine Nelson and Olson-Paper with Lissianski-Patent. As described in my discussion for claims 1 and 17 of the '147 Patent, Nelson discloses that HBr reacts with activated carbon to form an "improved mercury sorbent." Nelson also discloses that injecting that brominated mercury sorbent into a mercury-containing gas improves the ability to capture mercury, as compared to untreated activated carbon.

468. Lissianski-Patent discloses that some types of coal tend to have "low chlorine (Cl) content" natively, which results "in relatively high levels of elemental

[791] Ex. 1012 (Nelson) at 2:36-44

mercury in the flue gas from low rank coal."[792] Lissianski-Patent discloses a process for increasing the concentration of halogen-containing promoter (including HBr) in a mercury-containing gas, by supplying a "halogen agent" (gold) to the mercury-containing gas (green)."[793]

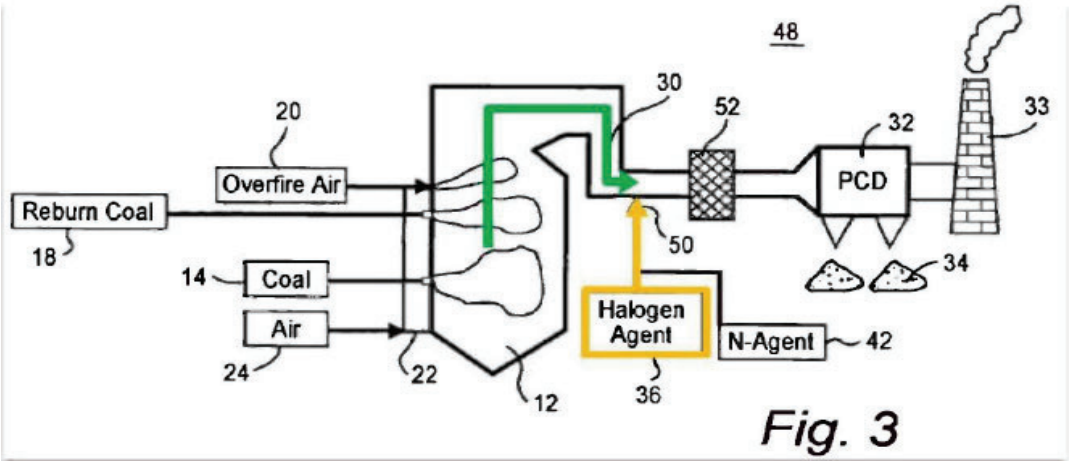


Fig. 3

469. Lissianski-Patent teaches supplying a stream of NH_4Br, NH_4C1, and/or NH_4I and a separate stream of activated carbon, directly into a mercury-containing flue gas. Lissianski-Patent discloses introducing the halogen-containing materials (including NH_4Br) with "flue gas temperatures of, for example, 1600°F to 2300°F," and are transported to the flue gas with "air, recycled flue gas, nitrogen or another carrier gas" in order to improve mixing.[794] Upon exposure to flue-gas temperatures,

[792] Ex. 1036 (Lissianski-Patent) at 1:52-67.
[793] Ex. 1036 (Lissianski-Patent) at Fig. 3 (annotated).
[794] Ex. 1036 (Lissianski-Patent) at 4:19-21; *see also* claim 24 ("air, *recycled flue gas* and nitrogen gas").

the NH_4Br, NH_4C1, and NH_4I vaporize and decompose into HBr, HCl, and HI, respectively.

> It has been discovered that mercury removal can be significantly improved by injecting ammonium chloride (NH_4C1), NH_4Br, or NH_4I into flue gas, especially in the flue gas from low-rank coals. The hot flue gas causes the additive to thermally decompose to form HCl, HBr or HI which results in more significant mercury oxidation.[795]

As such, the halogen-containing promoter (e.g., HBr) is in gaseous or vapor form when it reacts with the activated carbon. Lissianski-Patent describes that an "increase in mercury oxidation allows for improved efficiency of mercury removal by activated carbon (AC) injection, wet flue gas desulfurization (FGD) systems, and other mercury control technologies."[796]

470. In addition to improving the efficiency of mercury removal, Lissianski-Patent describes that another benefit of increased halogens in the mercury-containing flue gas is that they help with NOx reduction, another harmful pollutant, "by reducing oxides of nitrogen to molecular nitrogen."[797] Lissianski-Patent explains that a coal-combustion plant with an SCR unit can "relatively easily achieve 80% NOx reduction," and that an ammonium bromide (NH_4Br) and/or ammonium chloride (NH_4C1) additive can also "increase efficiency of NOx reduction" in a SCR

[795] Ex. 1036 (Lissianski-Patent) at 3:42-48.
[796] Ex. 1036 (Lissianski-Patent) at 3:47-50; *see also* Ex. 1036 (Lissianski-Patent) at claim 8.
[797] Ex. 1036 (Lissianski-Patent) at 3:23-25; *see also* 1:35-40.

process.[798] In addition to the NOx removal, other benefits described by Lissianski-Patent for providing a halogen-containing promoter to the mercury-containing gas are further oxidizing mercury, thus making it more susceptible for removal on activated carbon or in a wet scrubber.[799]

471. A person of skill in the art would have been motivated to combine Nelson and Lissianski-Patent, and have had a reasonable expectation of success in doing so, in starting with the disclosure of Nelson to inject the "improved mercury sorbent" of Nelson (i.e., the pre-brominated sorbent prepared according to Nelson's disclosure) into the mercury-containing flue gas. A POSITA would have also supplied additional halogen-containing promoter to the mercury-containing flue gas (as taught by Lissianski), upstream of the sorbent of Nelson. A POSITA would have recognized the advantages in this combination to: further oxidize mercury, and make it more susceptible for removal by activated carbon and/or a wet scrubber (thereby reducing mercury emissions); and also to enhance removal of oxides of nitrogen (NO), thus achieving multi-pollutant control. A POSITA would have recognized that, in implementing the teachings of Nelson in a plant with a selective catalytic reduction (SCR) unit, the plant may have already added halogen agents to mercury-containing gas to remediate NOx (as taught by Lissianski-Patent).[800]

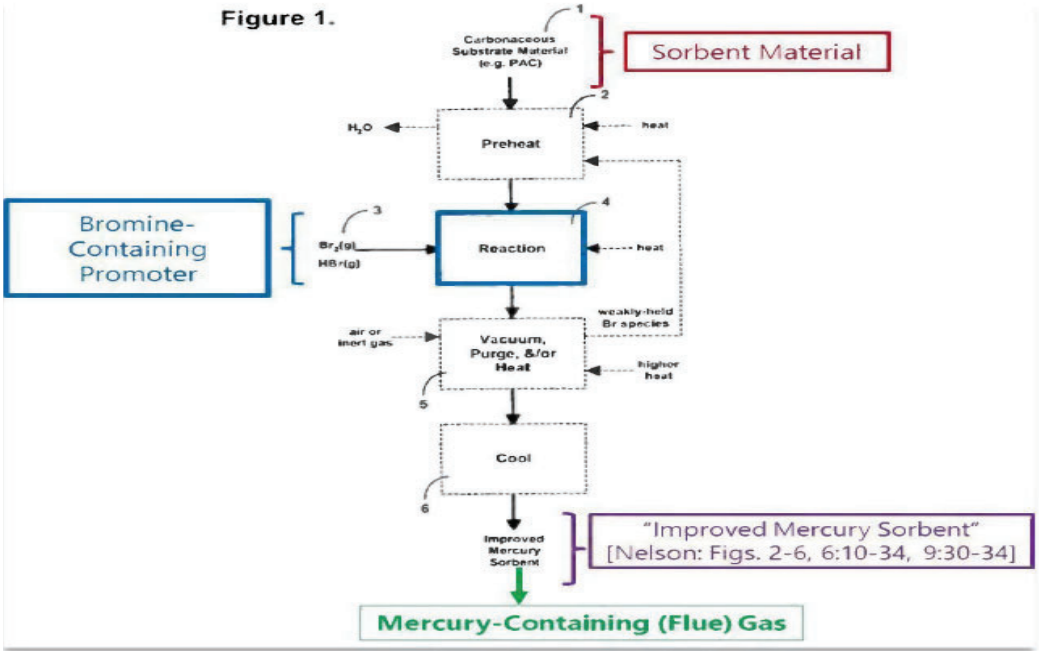
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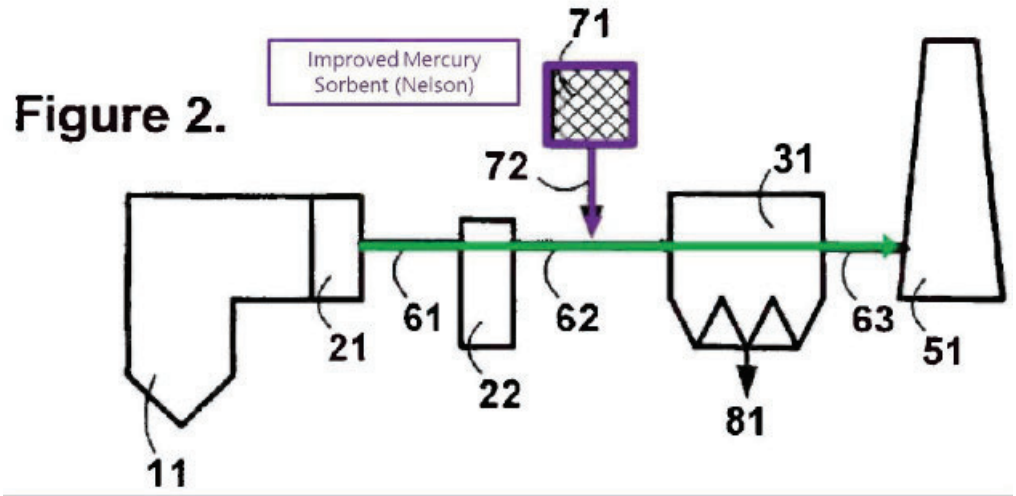
[798] Ex. 1036 (Lissianski-Patent) at 4:55-59; *see also* Ex. 1036 (Lissianski-Patent) at 2:61-64 (describing Fig. 3), 3:51-58, 4:46-54

[799] Ex. 1036 (Lissianski-Patent) at 1:35-40, 3:42-50.

[800] Ex. 1012 (Nelson) at 10:37-39; Ex. 1036 (Lissianski-Patent) at 2:61-64, 3:51-58, 4:43-59

472. In the combined system, nothing would need to have been taken away from the process of Nelson, because Nelson already describes injecting (pre-brominated) "improved mercury sorbent" (purple) into a mercury-containing gas (green).

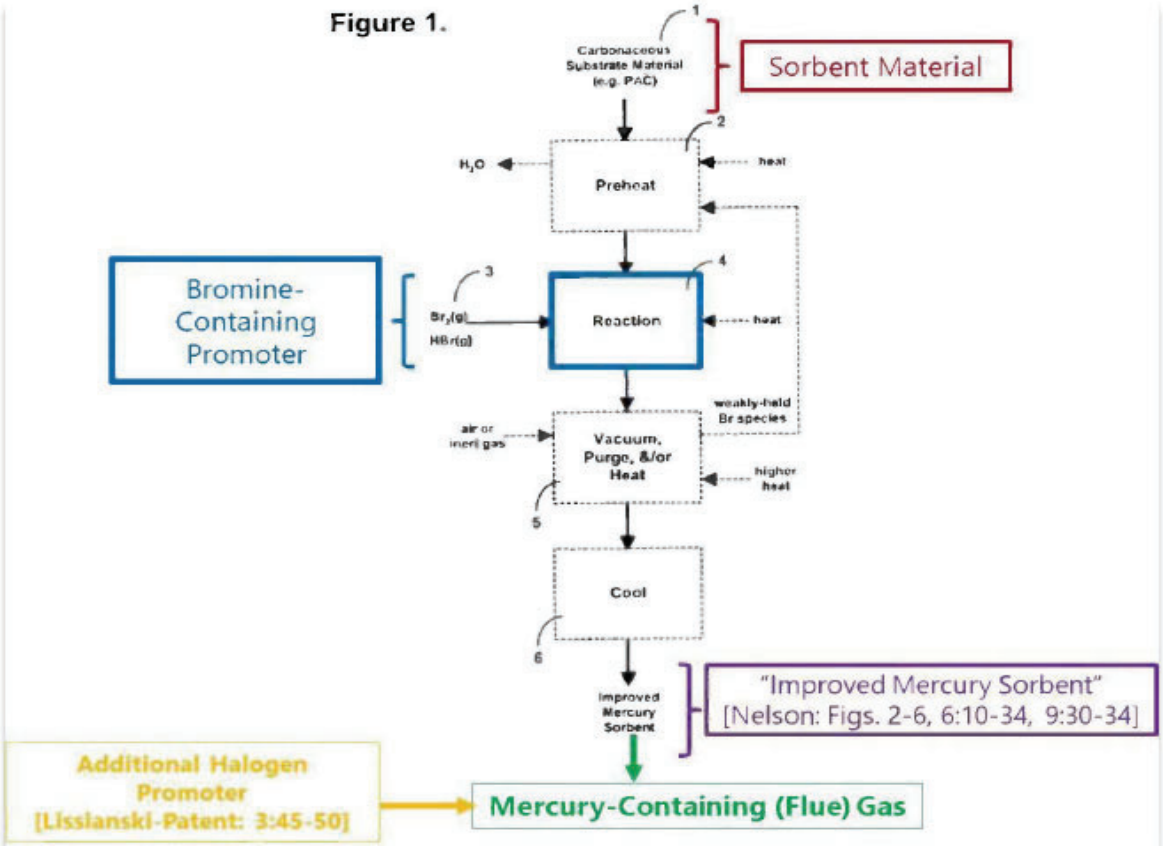


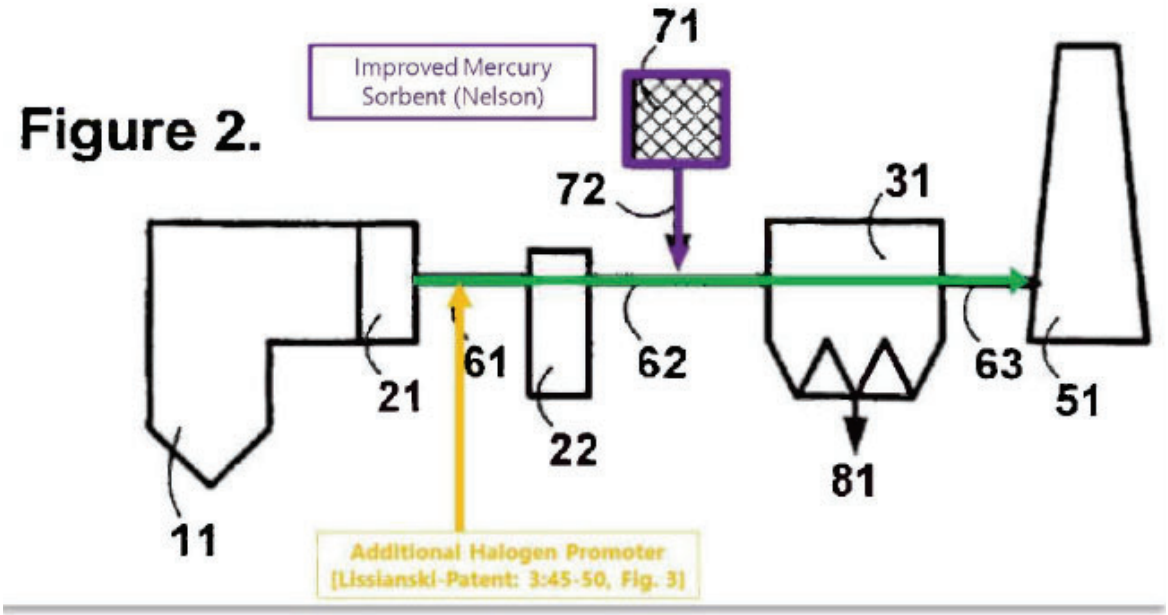


473. As taught by Lissianski-Patent, a POSITA would have supplied NH_4Cl and/or NH_4Br to mercury-containing gas, in which it forms HCl and/or HBr. Lissianski-Patent describes supplying halogen promoters to the mercury-containing gas.[801] A POSITA would have introduced these additional halogen promoters upstream of the SCR unit (item 52) and upstream of the particulate collection device (PCD, item 32), as described by Figs. 1-3 of Lissianski.[802]

474. Thus, the additional-halogen promoter (orange) of Lissianski-Patent would be added to Nelson as follows:

[801] Ex. 1036 (Lissianski-Patent) at Figs. 1-3, 4:14-60.
[802] Ex. 1036 (Lissianski-Patent) at 4:14-60, Figs. 1-3.


Figure 1.
Carbonaceous Substrate Material (e.g. PAC)
Sorbent Material
Preheat
heat
Bromine-Containing Promoter
Reaction
heat
weakly-held Br species
Vacuum, Purge, &/or Heat
higher heat
Cool
Improved Mercury Sorbent
"Improved Mercury Sorbent" [Nelson: Figs. 2-6, 6:10-34, 9:30-34]
Additional Halogen Promoter [Lissianski-Patent: 3:45-50]
Mercury-Containing (Flue) Gas


Figure 2.
Improved Mercury Sorbent (Nelson)
71
72
31
21
61
62
63
51
22
81
11
Additional Halogen Promoter [Lissianski-Patent: 3:45-50, Fig. 3]

Combining the pre-brominated sorbent of Nelson (purple) in mercury-containing gas (green) with additional halogen (orange) of Lissianski-Patent beneficially provides multi-pollutant control, enhancing removal of both NOx and mercury.

475. A POSITA would have been further motivated to combine these references because all three references are from the same field of endeavor, namely, using halogens (promoters) with activated carbon (sorbent) in order to remove mercury from combustion gas streams. The references solve the same problem, increasing the effectiveness of mercury removal. Nelson "relates to the removal of mercury from combustion gas streams and more specifically to the use of halogenated carbon materials to reduce the emissions of mercury from coal-fired plants."[803] Similarly, the title of Olson-Paper is "Chemical mechanisms in mercury emission control technologies."[804] The title of Lissianski-Patent is "Methods for removal of mercury emissions from coal combustion."[805]

476. A POSITA would also have had a reasonable expectation of success, and have been motivated to combine, because Nelson and Lissianski-Patent teach the same sorbent to remove mercury (activated carbon), each teach improving the effectiveness of that sorbent in removing mercury by using the same promoter

[803] Ex. 1012 (Nelson) at 1:24-28.
[804] Ex. 1079 (Olson-Paper) at Title.
[805] Ex. 1036 (Lissianski-Patent) at Title.

(HBr), and each teach using the promoter in the gas phase to improve mercury capture on activated carbon. Nelson states:

> [T]he simple act of exposing a carbonaceous material, preferably powdered activated carbon (PAC), to gaseous bromine, Br_2 (g), or to gaseous hydrogen bromide, HBr(g), significantly increases the carbonaceous material's ability to remove mercury species when injected into high-temperature coal-fired flue-gas compositions [806]

In a similar manner, Lissianski-Patent states that the same bromine-containing components as Nelson, namely HBr and/or HCl, "increases the amount of mercury removal by activated carbon injection."[807] Olson-Paper also confirms the importance of halogens to promote mercury capture using activated carbon, because "[w]ithout either HCl or NO_2 in the gas stream, the carbon sorbents are ineffective, and immediate breakthrough occurred."[808]

477. A person of skill in the art would have been motivated to provide additional halogen-containing promoter directly into the flue gas (as disclosed by Lissianski) in conjunction with injecting the improved mercury sorbent of Nelson into the flue gas (as disclosed in Nelson) in order to improve mercury removal (as taught by both Nelson and Lissianski) and also to improve the effectiveness of the NOx removal processes. A person of skill in the art would have had a reasonable expectation of success that the process would achieve desirable results in increasing

[806] Ex. 1012 (Nelson) at 6:10-15.
[807] Ex. 1036 (Lissianski-Patent) at 3:20-27, 3:45-47.
[808] Ex. 1079 (Olson-Paper) at 980.

removal of both NOx and mercury: (a) both Nelson and Lissianski-Patent contemplate that power plants already include an SCR unit for NOx removal; and (b) Lissianski-Patent describes that providing additional bromine would improve the functioning of the SCR units in removing NOx. Moreover, Nelson, Lissianski, and Olson-Paper recognized the advantages of oxidizing mercury to make it more susceptible to removal.[809] The additional halogen-containing promoters provided to the mercury-containing gas, as in Lissianski, accomplishes the goal of oxidizing mercury in the gas-phase. In combining the references, nothing would need to be taken away from the process in Nelson, or the chemical reaction mechanisms disclosed in Olson-Paper.

1. Motivation to Combine to Enhance Removal of NO_X

478. A person of skill in the art would have been motivated to combine the teachings of Nelson and Olson-Paper with Lissianski-Patent in order to accomplish multi-pollutant control—to use one process to remove multiple noxious pollutants.

479. First, both Nelson and Lissianski-Patent disclose NOx as a byproduct of coal combustion.[810] For example, Nelson contemplates the prominence of NO_x (oxides of nitrogen) as a pollutant in that he specifically includes this component when "simulat[ing] a combustion gas stream."[811] Second, both references disclose

[809] Ex. 1012 (Nelson) at Fig. 12; Ex. 1036 (Lissianski-Patent) at 3:14-16; Olson-Paper at 979.
[810] Ex. 1012 (Nelson) at 11:46-48; Ex. 1036 (Lissianski-Patent) at 1:9-13.
[811] Ex. 1012 (Nelson) at 11:46-48; *see also* 13:4, 13:47, 13:58, 15:21, Fig. 11.

power plants with a selective-catalytic reduction (SCR) unit, which reduces harmful NOx into harmless molecular nitrogen (N_2).[812] Nelson contemplates that using the invention in conjunction with "Selective catalytic reduction (SCR) units for NOx reductions, or flue gas conditioning systems to improve particulate removal, could also be placed in the equipment arrangements. The utility of the disclosed mercury-removal method would be unaffected, however."[813] As I discuss above in in the State of the Art,[814] it was well-known in the art to include SCR and SNCR systems to remove nitrogen oxides (NO_x), another toxic pollutant emitted from coal combustion. A POSITA would understand that the utility of an SCR would "be unaffected," using Nelson alone, because in Nelson the pre-brominated carbon is injected downstream of the SCR.

480. Similar to Nelson, Lissianski-Patent also discloses the need to remove nitrogen oxides, stating that the "injected additive also reduces NOx emissions in a selective catalytic reduction (SCR) and/or (SNCR) process."[815] Lissianski-Patent explains that a coal-combustion plant with an SCR unit that can "relatively easily achieve 80% NOx reduction," and that an ammonium bromide (NH_4Br) additive can also "increase efficiency of NOx reduction" in a SCR process.[816] Lissianski-Patent

[812] Ex. 1012 (Nelson) at 10:34-37; Ex. 1036 (Lissianski-Patent) at 2:60-64, 3:51¬58.
[813] Ex. 1012 (Nelson) at 10:34-37.
[814] See State of the Art, above, §§ VIII.B.4, VIII.B.5VIII.B.5.c
[815] Ex. 1036 (Lissianski-Patent) at 3:51-53; *see also* 4:43-59 (describing Fig. 3).
[816] Ex. 1036 (Lissianski-Patent) at 4:55-61; *see also* Ex. 1036 (Lissianski-Patent) at 2:61-64 (describing Fig. 3), 3:51-58, 4:46-54.

explains that adding ammonium bromide directly "into flue gas, especially in the flue gas from low-rank coals," provides multipollutant control in that it: (a) "allows for improved efficiency of mercury removal by activated carbon (AC) injection"; and (b) the ammonium bromide "also reduces NOx emissions in a selective catalytic reduction (SCR) and/or (SNCR) process."[817] Accordingly, both Nelson and Lissianski-Patent teach the presence of an SCR unit as part of the already-existing pollution-control systems of a power plant. A POSITA would have thus been motivated to start with the disclosure of Nelson of supplying an improved mercury sorbent into the mercury-containing (flue) gas, and then supplying *additional* halogen-containing promoter (NH_4Br, which gets converted in the gas phase to HBr) upstream of the sorbent injection of Nelson. Providing additional halogens in the flue gas would advantageously increase the effectiveness of the SCR in removing NO_x—and have the co-benefit of further increasing mercury removal.

2. Motivation to Combine to Enhance Removal of Mercury

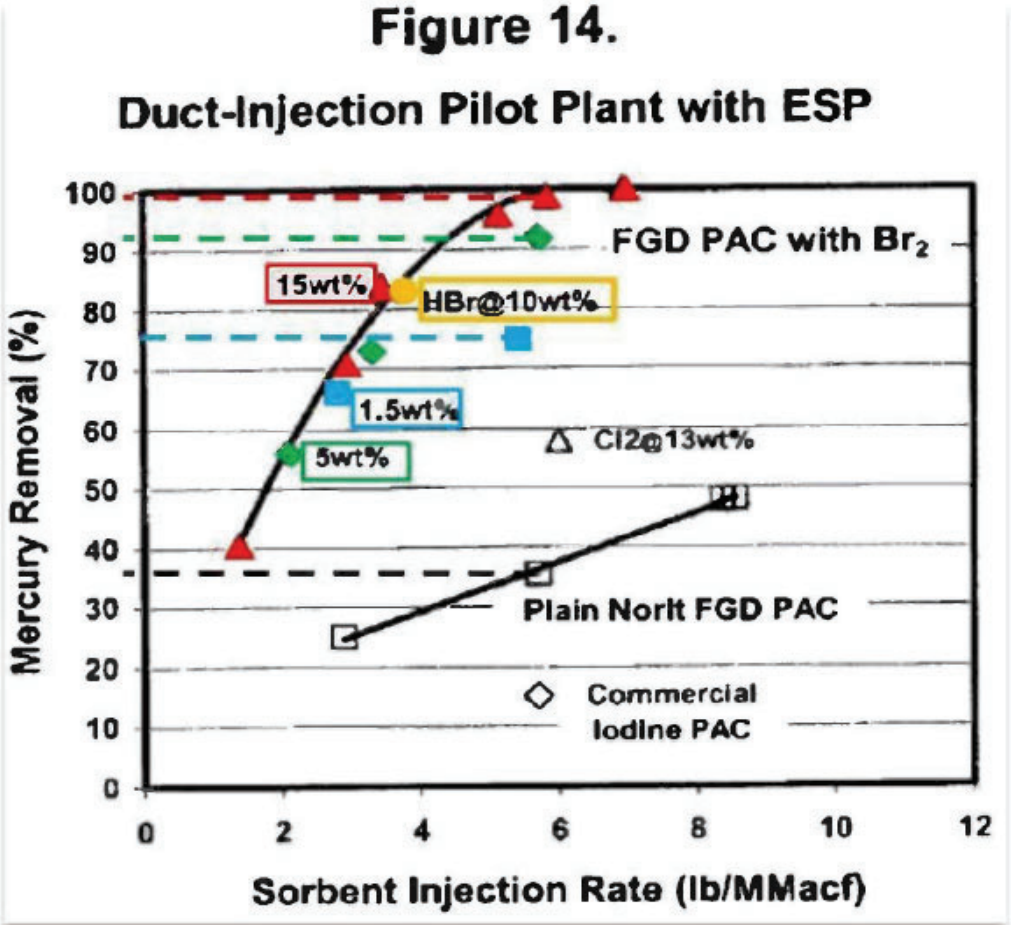
481. Based on the teachings of Nelson, a person of skill in the art would have been motivated to increase the concentration of halogen-containing promoter in the flue gas (such as the HBr disclosed in Lissianski-Patent), not only to remove NO_x (as per Lissianski-Patent) but also to further improve the efficiency of mercury removal.

[817] Ex. 1036 (Lissianski-Patent) at 3:44-55

482. As described in Ground M for claim 17, Nelson describes embodiments in which the bromine-promoted sorbent is prepared through an in-flight reaction between a bromine-containing gas and powdered activated carbon (PAC). The bromine-promoted sorbent is then stored, transported, and then injected into a mercury-containing gas.[818]

483. Nelson taught that "improved mercury sorbent" was manufactured with less than 30 wt% bromine. This is because although "some powdered activated carbons" could hold "over 30 wt%" of bromine, the bromine could have been "held at less-energetic sites" and would desorb.'[819] Indeed, it was known since the 1970s that the saturation limit (adsorption equilibrium) of bromine on activated carbon was around 31-38%.[820] Accordingly, Nelson provided examples, shown in Fig. 14, annotated below, in which different curves are plotted with less than 30 wt% bromine on the sorbent.

[818] Ex. 1012 (Nelson) at Figs. 1-6, 9:21-34.
[819] Ex. 1012 (Nelson) at 8:35-57.
[820] *See* State of the Art, above, § VIII.C.3.



Nelson shows using Br_2(g) to load activated carbon with 1.5 wt% bromine (indicated by the ■) 5 wt% bromine (indicated by the ♦) and 15 wt % bromine (indicated by the ▲).[821] Fig.14 also shows using hydrogen bromide (HBr) to load the activated carbon with 10 wt% bromine (indicated by the ●). Accordingly, the improved mercury sorbent of Nelson, added to bin 71 and injected into a mercury-containing gas, was not fully saturated with bromine-containing promoter, and would be capable of holding more.

[821] Ex. 1012 (Nelson) at Fig. 14, 8:35-53.

484. Nelson also taught that, despite the advantages of increasing bromination of activated carbon to higher weight ratios, offsite bromination at increased concentrations presented engineering challenges (bromine desorption during storage and transportation) and economic considerations (more cost and time to produce).[822]

485. As taught by Nelson in view of Olson-Paper and Lissianski-Patent, a person of skill in the art wanting to increase removal of mercury, without increasing the activated-carbon injection rate (a component more costly than bromine-containing promoter), would have been motivated to increase the effectiveness of the improved mercury sorbent of Nelson by adding additional halogens (e.g., the HBr of Lissianski-Patent) to the mercury-containing gas. Increasing halogen concentration in the mercury-containing gas, such as the concentration of HBr and/or HCl, would: (a) increase the fraction of oxidized mercury in the mercury-containing gas, thus making the mercury more susceptible to removal via the *basic binding sites* on activated carbon and/or a web scrubber;[823] and (b) increase the weight ratio of bromine on the pre-brominated sorbent of Nelson, such that *additional promoted sites* on activated carbon would be available to react with elemental mercury. I

[822] Ex. 1012 (Nelson) at 8:51-56.

[823] Ex. 1036 (Lissianski-Patent) at 6:33-7:6 (discussing Figs. 8-9); Abstract; 1:22–42; 1:65-67; 3:14-50; Ex. 1012 (Nelson), Fig. 12; Ex. 1079 (Olson-Paper) p. 979.

further discuss the reactions of oxidized mercury and elemental mercury with the various sites of activated carbon in the obviousness grounds based on Nelson below.

XVIII. INVALIDITY UNDER 35 U.S.C. 112

486. Claim 17 of the '147 patent lacks written description. Claim 17 of the '147 patent requires that step of "injecting separately the bromine containing promoter into a gas stream." I understand that under the Plaintiff's theory of infringement, that step is met by combusting a mixture of coal and a bromine additive. I have reviewed the specification of the '147 patent, and there is no description of combusting a mixture of coal that has been pretreated with a bromine additive. I have reviewed each of the example experiments described in the '147 patent (Examples 1-12), and none of those examples describe the pretreatment of the coal that is to be combusted with a bromine additive.

487. Claim 17 of the '147 patent is not enabled. Claim 17, through its dependency on Claim 1, requires the step of:

> (a) promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter to form a promoted brominated sorbent, wherein the bromine containing promoter is in gaseous form, vapor form, or non-aqueous liquid form, and wherein the activated carbon contains graphene sheets having carbene species edge sites which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury.

488. I agree that it is possible that using a bromine additive in a system with an activated carbon sorbent material may result in the formation of the promoted brominated sorbent described above (via in-flight bromination). But the '147 patent does not teach a person of skill in the art (POSA) the proper conditions to ensure that such a promoted brominated sorbent is formed through the use of pretreating coal with the bromine compound. Likewise, the '147 patent does not instruct a POSA in any analytical techniques to determine whether or not the claimed promoted sorbent is formed. In my opinion, it would be quite difficult for a POSA to measure to see if the promoted sorbent had been found, and also whether the promoted brominated sorbent is responsible for the removal of mercury as required by the claims.

489. It is well known that the addition of bromine into a coal combustion system can also facilitate the removal of mercury by oxidizing elemental mercury in the gas phase, followed by absorption of the oxidized mercury species in an FDG scrubber or onto a sorbent. In fact, this is the technical basis for the patent by Lissianski et al.[824] This patent presents results from a computer simulation with only chemical reactions among species in the gas phase; i.e., homogeneous chemistry. Oxidation and sorption of mercury on all solids, including UBC and PAC, were omitted from the simulation. The results show that injection of 500 ppm of NH_4Cl

[824] Ex. 1039 (Lissianski-Patent).

into the upper furnace elevations homogeneously oxidized 12% of the Hg^0 into $HgCl_2$. Additional calculations showed that the performance with NH_4Cl could be matched by NH_4Br at a concentration that was ten times lower, because at furnace temperatures highly reactive Br-atoms are present at much greater concentrations than Cl-atoms. This so-called homogenous mercury oxidation is not within the scope of Claim 1 of the '147 patent, which requires that bromine first react with carbene species edge sites in a PAC sorbent to form a carbocation paired with a bromide anion in the promoted brominated sorbent, which then reacts with the mercury. Since Claim 1 describes only a heterogeneous mercury reaction process on promoted PAC, the teaching of the '147 patent does not instruct a POSA how to ensure or determine that the claimed heterogenous path happens instead of the homogenous path.

490. All of the claims of the '225 patent lack written description of the combustion of a mixture of coal with a bromine additive. I have reviewed the specification of the '225 patent, and there is no disclosure anywhere of the addition of bromine into a combustion chamber, either as an additive on the coal or separately. The specification mentions only that the inventive *sorbent* can be injected "where desired (e.g., before, after or within the boiler)." All of the examples involve addition of bromine after the boiler, or the use of bromine to prepare a brominated sorbent outside the system.

491. Each of the ’114, ’517 and ’430 patents lack sufficient written description of the addition of a bromine species to the coal upstream (or before) the combustion chamber. Each of those patents reports essentially the same example experiments, and none of those experiments involve the addition of any bromine species to the coal. Nor is there a general description of the addition of a bromine species to the coal. Rather, throughout the specification, the bromine species is either added to the flue, or is mixed with the sorbent outside of the system. I understand that plaintiff may point to Figure 6 of the ’114 patent (which is Figure 11 of the ’430 and ’517 patents), which shows arrows coming from the term “additive injection” going before, into and after the boiler. But none of those arrows point to the coal shown in the diagram. The arrow pointing to before the boiler is not directed to the coal, but would be understood by a POSA to refer to injection into, for example, secondary and tertiary air streams, low-NOx OFA streams, flue gas recirculation, or the primary stream from the pulverizer into the boiler. Injecting an additive “before … the boiler” could also involve a specialized additive injection system leading to the boiler that does not interact with the coal before being introduced to the combustion chamber.

492. Each independent claim of the ’225 patent requires the presence of pyrolysis char in the combustion step. Claims 1 and 17 of the ’225 patent require the step of “combusting a mixture comprising coal, pyrolysis char, and a [bromine]

additive." Claims 14 and 16 require combusting coal in a combustor that includes pyrolysis char. There is no written description for this use of pyrolysis char, and no practical effect for the method of treating a mercury-containing gas. There is no mention of pyrolysis char as a component of the combustion mixture or in the combustion chamber anywhere in the specification. There are no experiments describing the use of char in the combustion chamber.

493. The only mention of pyrolysis char in the specification is in the long lists of examples of the activated carbon sorbent. See Claim 8, for example. But each claim of the '225 patent already has a *separate* element requiring the use of an activated carbon particulate sorbent material. The requirement of having pyrolysis char present in the combustion mixture or chamber is unrelated to the activated carbon sorbent requirement. Thus, the only written description support for pyrolysis char is as a type of activated carbon sorbent, not as a component of the combustion mixture.

494. There would be no reason to add pyrolysis char to the combustion mixture or combustion chamber. Pyrolysis char in this context is understood as the carbonaceous material that remains from a carbon-based material after any volatiles are driven off during heating. Pyrolysis char is primarily carbon, and is combustible. Almost all the pyrolysis char present in the combustion zone of a coal combustor would largely expect to combust to form carbon dioxide, steam, and minor amounts

of carbon monoxide.[825] The very small residual amounts of unburned carbonaceous material are called UBC, which has grossly different characteristics than pyrolysis char. Due to the exposure of char to very hot temperatures in the furnace, UBC anneals into more crystalline forms and is much less reactive than pyrolysis char.[826] I have reviewed the testimony of one of the inventors, Michael Holmes, and he was unable to identify any purpose or role that pyrolysis char would have in the combustion zone.[827] That is consistent with my view.

495. I understand that plaintiffs might argue that the presence of pyrolysis char in the combustion zone may lead to some pyrolysis char escaping without combusting into the flue where it can be a sorbent for mercury. I would first note that there is no description of that scenario in the '225 patent. Furthermore, in my experience, particulate carbon material that is leaving the combustion zone is generally referred to as unburnt carbon, rather than pyrolysis char. Unburnt carbon (UBC) is fundamentally different than pyrolysis char in that it is always exposed to very high temperatures in the flame zone. UBC levels are very small fractions of the

[825][825] Ex. 2004 (Holmes Dep.) at 94:22-95:1.

[826] Ex. 1094. Robert H. Hurt, Kevin A. Davis, Nancy Y. C. Yang, Thomas J. Headley, Gareth D. Mitchell. Residual carbon from pulverized-coal-fired boilers 2. Morphology and physicochemical properties. Fuel 74(9):1297-1306 (1995).

[827] Ex. 2004 at 124:7-125:5.

amounts of pyrolysis char formed directly by heating, and UBC contains hardly any heteroatoms (H, O, N, S) so its reactivity is much lower than pyrolysis char's.[828] Consequently, it would be incredibly inefficient to add pyrolysis char to the combustion zone in the hopes that some would survive combustion and make it to the flue, rather than to simply add it to the flue directly. No POSA would use pyrolysis char as a sorbent in such an inefficient way.[829]

496. I understand that plaintiffs have asserted that the pyrolysis char element discussed here need not be separately added to the combustion zone, but that the claim element can be met whenever coal is combusted, because some pyrolysis char would be formed as a byproduct from the combustion of the coal. There is no written description of the formation of pyrolysis char in this way in the '225 patent. Furthermore, this theory makes the claim element even more mysterious. Under the plaintiffs theory, pyrolysis char is an intermediary that is formed during the combustion of coal, but would then largely be burned away. The process occurs anytime that coal is being combusted, and thus is not an improvement in mercury capture. In my opinion, the temporary presence of pyrolysis char in the combustion zone is unlikely to have any significant effect on mercury capture, and the '225 patent does not suggest otherwise.

[828] Ex. 1094.
[829] Ex. 1094

497. The pyrolysis char term is also not enabled. The ’225 patent does not mention any disclosure of pyrolysis char in the combustion zone until the claims, so a POSA would not know its role in mercury capture with the invention. With most coal types char comprises about half the coal mass, nearly all coal minerals, and most of the carbon in the coal, but relatively little of the oxygen, sulfur, and hydrogen. However, char yields with lignite are only about one-third the coal mass and with low volatility coals, the yields can exceed 90 %. Moreover, char burning rates in furnaces vary by more than an order of magnitude among coals across the rank spectrum.[830] The specification offers no guidance on how to measure the amount of char in a particular furnace, and, when asked, one of the inventors admitted that he did not know how to measure it.[831] Consequently, a POSA would have no way to tell if a particular coal combustion system falls within the claims or not because the ’225 patent says nothing about the variations in chars’ formation and oxidation. Without such basic guidance a POSA could not possibly understand pyrolysis char’s role in mercury control in the ’225 patent. In fact, a POSA would not expect pyrolysis char that is either fed into or that inevitably forms within a boiler to play any role at all in

[830] Ex. 1096. S. Niksa, G.-S. Liu, and R. H. Hurt. Coal conversion submodels for design applications at elevated pressures. Part I. Devolatilization and char oxidation. Prog. Energy Combust. Sci., 29(5):425-477 (2003)
[831] Ex. 2004 at 134:15-24.

mercury control because none of its combustion products change the fact that all mercury is present as gaseous Hg^0 within boilers.[832]

498. Certain dependent claims of the ’225 patent also require that the pyrolysis char present in the combustion mixture or combustion zone be a “promoted pyrolysis char.” This requirement only underlines the lack of written description and enablement of the pyrolysis char term. To form a promoted pyrolysis char, the pyrolysis char would need to react with bromine. But the claims require the presence of the promoted pyrolysis char in the combustion mixture or combustion chamber. The temperatures of a typical combustion chamber are too high for the formation of a promoted pyrolysis char in the combustion chamber. There is no teaching in the ’225 patent for how to promote pyrolysis char in the combustion chamber, and it would be impossible because of the high temperatures. The difficulty in forming a promoted pyrolysis char in the combustion zone, and the failure of the ’225 patent to mention it, only furthers my belief that the inventors of the ’225 patent did not foresee the use of pyrolysis char in the combustion mixture/chamber as a way of treating a mercury-containing gas.

XIX. GROUND A: OBVIOUSNESS OF THE ’114 PATENT OVER SJOSTROM IN VIEW OF ECKBERG

[832] *Id*.

499. It is my opinion that Sjostrom in view of Eckberg render obvious each asserted claim of the '114 Patent.

A. INDEPENDENT CLAIM 1

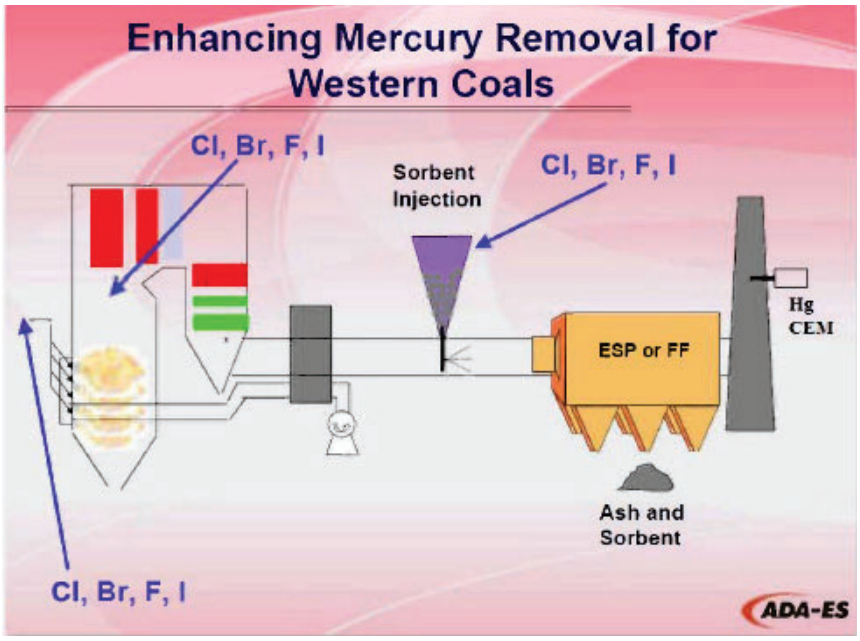
1. Claim 1: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

500. The preamble is disclosed by Sjostrom. Sjostrom teaches separating mercury from a mercury-containing gas. The title of Sjostrom is "Full Scale Evaluations of ***Mercury Control Technologies*** with PRB Coals."[833] Specifically, Sjostrom described various mercury control tests conducted at coal-fired power plants.[834] Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection and halogen addition, as detailed below.[835]

[833] Ex. 1010 (Sjostrom) at 1 (emphasis added).

[834] Ex. 1010 (Sjostrom) at 12, 18.

[835] Ex. 1010 (Sjostrom) at 4.



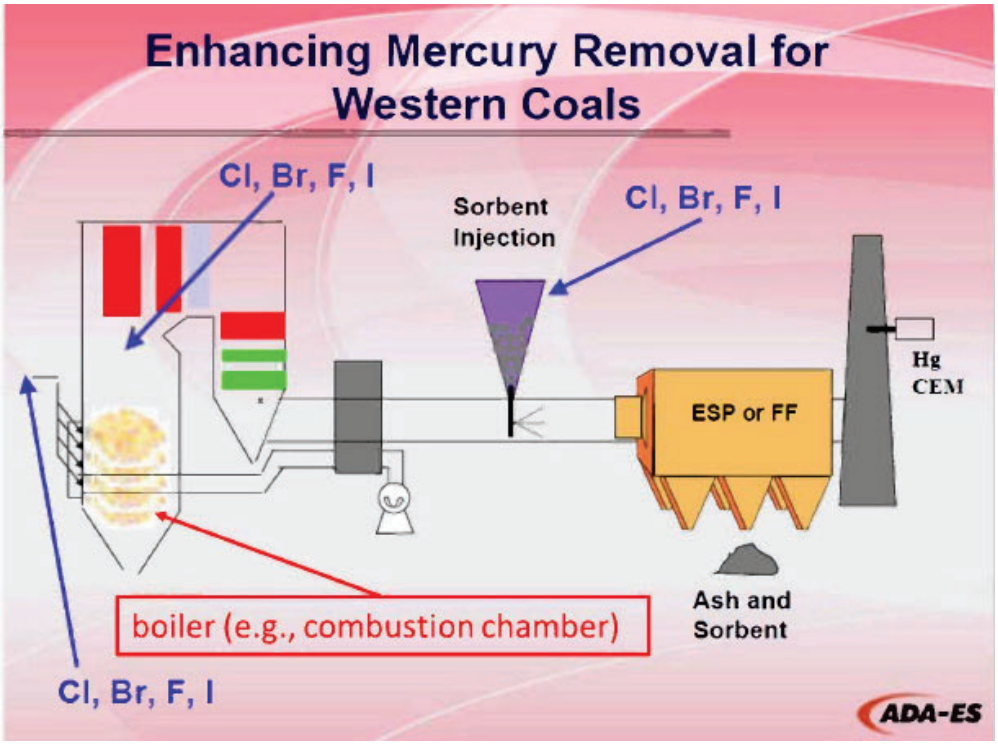
Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)" achieved throughout the testing performed on coal flue gas.[836] This annotated figure in Sjostrom specifically shows that particulate matter, including the mercury-sorbent composition, would have been separated from the flue gas by the ESP or FF, because a POSITA would have understood that it was well-known to use an ESP or FF to remove such solid materials.[837]

2. Claim 1: Element (1)(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas,"

501. This limitation is disclosed by Sjostrom. This limitation is also obvious over Sjostrom in view of Eckberg. As discussed above, Sjostrom described various

[836] Ex. 1010 (Sjostrom) at 8, 15-17, 20, and 21.
[837] State of the Art, § XII.B.5.a

mercury control tests conducted at coal-fired power plants.[838] These plants stage combustion of coal in a coal-fired boiler (e.g., combustion chamber) as shown in the annotated figure below.[839]

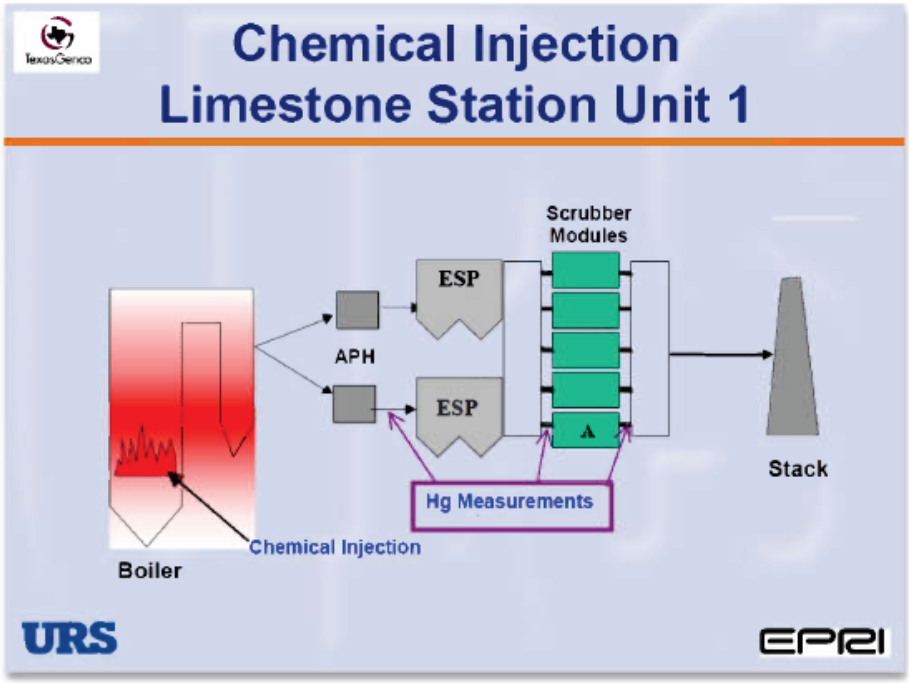


A POSITA would have understood that this unit was a boiler based on the image used to represent the unit in the drawing, which was a common and routine way to represent a coal-combustion chamber (boiler). Sjostrom explains that at the time of testing, both of the coal-fired power plants tested combusted PRB (Powder River Basin) coal having a mercury content of "0.04 — 0.1 ppm-dry.[840] Relying only on existing equipment at these plants, Sjostrom shows that the outlet mercury content

[838] Ex. 1010 (Sjostrom) at 12, 18.
[839] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[840] Ex. 1010 (Sjostrom) at 12, 18.

of the flue gas was 11.2 µg/dncm.[841] Thus, Sjostrom discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing flue gas stream.

502. To the extent that Sjostrom is found to not explicitly disclose a combustion chamber that is a boiler, Eckberg discloses this limitation. As shown in the figure below, Eckberg explicitly describes combusting coal in a boiler.[842]



The image in Eckberg identified as a "boiler" is substantially similar to the image found in Sjostrom. Thus, Sjostrom in view of Eckberg discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing flue gas stream.

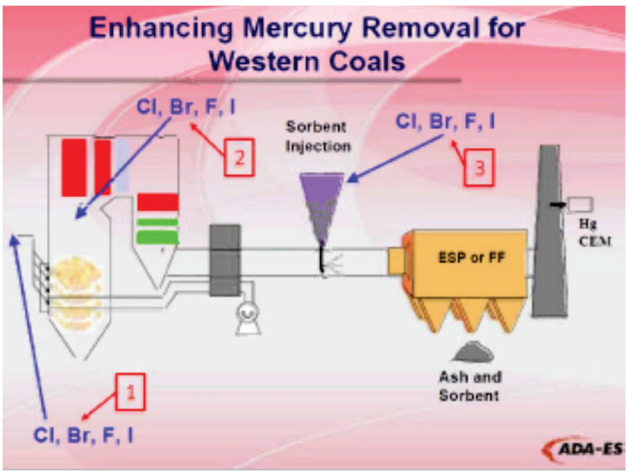
3. Claim 1: Element (1)(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br, or a combination thereof, wherein the coal comprises added Br2 HBr, Br, or a combination thereof,

[841] Ex. 1010 (Sjostrom) at 3.
[842] Ex. 1011 (Eckberg) at 5.

added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br2 HBr, Br, or a combination thereof, or a combination thereof;"

503. This limitation is disclosed by Sjostrom. This limitation is also obvious over Sjostrom in view of Eckberg.

504. This limitation is disclosed by Sjostrom, and obvious over Sjostrom in view of Eckberg under either interpretation. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[843] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal power process."[844]



Addition Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[845] Addition

[843] Ex. 1010 (Sjostrom) at 4.
[844] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[845] Ex. 1010 (Sjostrom) at 4 (annotations in red).

Location 2 of Sjostrom discloses injecting bromine into the boiler.[846] Location 3 of Sjostrom discloses adding bromine to the mercury sorbent that is injected into the flue gas.[847]

505. A POSITA would have found it obvious that the "Br" of Sjostrom would be a widely available bromine-containing material, such as HBr or an aqueous solution of a bromide salt, such as $CaBr_2$, for Addition Location 1 and Addition Location 2. Further, Sjostrom teaches the addition of "KNX (Alstom Power)."[848] KNX was a known aqueous solution of a bromide salt additive developed for enhanced mercury control. A POSITA would have found it obvious that an aqueous bromide salt solution, such as $CaBr_2$, would dissociate to form Br^- ions. As discussed above, Addition Location 1 of Sjostrom renders obvious adding bromine-containing species upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[849] Thus, Sjostrom renders obvious wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber.

506. As discussed above, Addition Location 2 of Sjostrom teaches adding bromine-containing species into the combustion chamber.[850] Thus, Sjostrom

[846] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[847] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[848] Ex. 1010 (Sjostrom) at 23.
[849] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[850] Ex. 1010 (Sjostrom) at 4 (annotations in red).

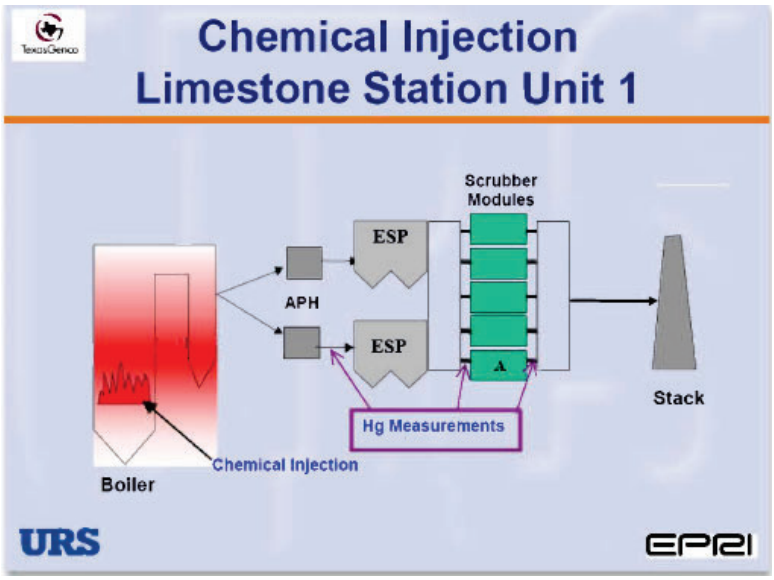
discloses wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof. For at least this reason, Sjostrom discloses this limitation under the first, broader interpretation.

507. A POSITA would have understood the "Br" addition of Sjostrom would also have entered the mercury-containing flue gas. Specifically, a POSITA would have understood the "Br" added at either Addition Location 1 before the combustion chamber or Addition Location 2 within the combustion chamber would have resulted in "Br" entering the flue gas stream. A POSITA would have found it obvious that the "Br" of Sjostrom could be an aqueous solution of a bromide salt, such as $CaBr_2$, for Addition Location 1 and Addition Location 2. Further, Sjostrom teaches the addition of "KNX (Alstom Power)" as the bromine-containing ingredient.[851] KNX was a known aqueous solution of a bromide salt additives developed for enhanced mercury control. A POSITA would have found it obvious that an aqueous bromide salt solution, such as $CaBr_2$, would dissociate to form Br ions. A POSITA would have understood that at combustion temperatures found within the boiler, at least a portion of the Br^- ions injected at either Addition Location 1 or Addition Location 2 would have evaporated, leaving the boiler as HBr and Br in the vapor phase. Thus, Sjostrom discloses wherein the mercury-

[851] Ex. 1010 (Sjostrom) at 23.

containing gas comprises a halogen or halide promoter comprising HBr, Br, or a combination thereof.

508. To the extent that Sjostrom does not explicitly identify the bromine-containing species, Eckberg teaches this limitation. As shown in the figure below, Eckberg teaches "chemical injection" to the boiler.[852]



Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" and "$CaBr_2$ (52 wt%)" into the boiler.[853] A POSITA would have understood that calcium bromide was an example of a "bromide compound," and that a 52 wt% aqueous solution of $CaBr_2$ would have dissociated in water to form a quantity of Br^- ions. A POSITA would have found it obvious that an aqueous bromide salt solution, such as $CaBr_2$, would dissociate to form Br ions. A POSITA would have further understood the bromide

[852] Ex. 1011 (Eckberg) at 5.
[853] Ex. 1011 (Eckberg) at 9.

ion (Br^-) added to the combustion chamber of Eckberg would also have entered the mercury containing flue gas. As described above in the "Reasons to Combine" section, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Eckberg (e.g., the injection of $CaBr_2$) to the combustion chamber of Sjostrom.

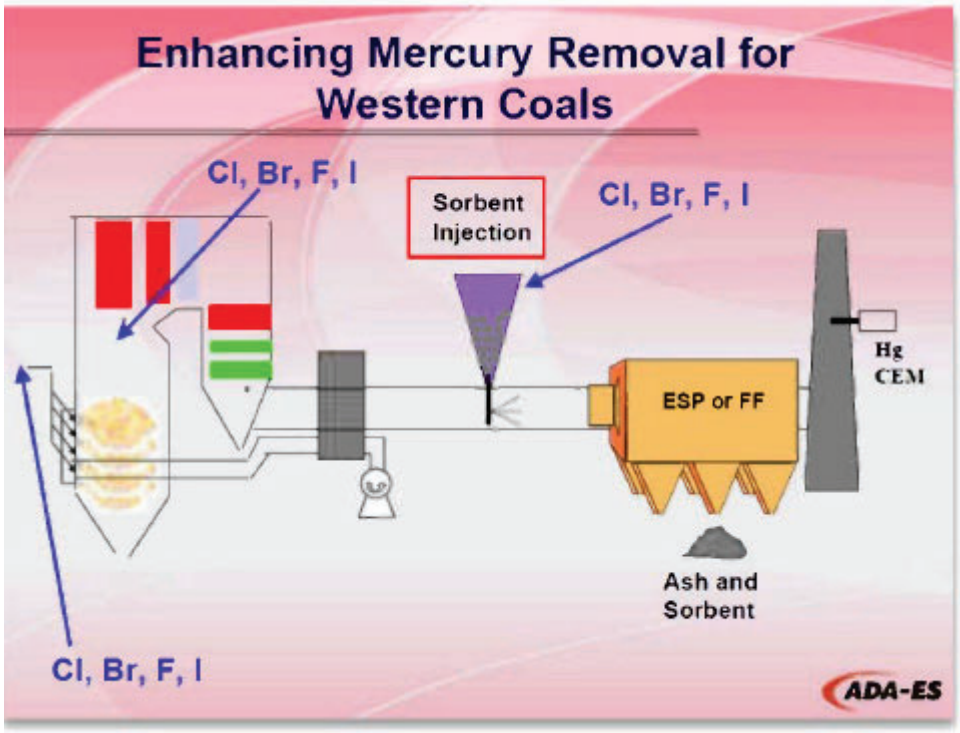
4. Claim 1: Element (1)(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;"

509. This limitation is disclosed by Sjostrom.

a. Injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber

510. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[854]

[854] Ex. 1010 (Sjostrom) at 4 (annotations in red).



As shown in the above figure, the "Sorbent Injection" occurs downstream from a combustion chamber. Specifically, Sjostrom described testing performed with activated carbon injection, including injection of "DARCO FGD."[855] A POSITA would have understood that DARCO FGD was a well-known type of activated carbon used for mercury capture.[856]

b. **Contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition**

511. The mercury in the flue gas is adsorbed, and thus contacted, with the sorbent to form a mercury/sorbent composition. A POSITA would have understood

[855] Ex. 1010 (Sjostrom) at 10, 11, 16.
[856] See, e.g., State of the Art, Sections XII.C.3, XII.G.2.

that Norit DARCO FGD and related materials were referred to as a "sorbent" specifically because they adsorbed (and thus contacted) materials in the gas phase. It was a well-known use of activated carbon for adsorbing and thus removing mercury from the flue-gas stream. Upon adsorption, the mercury and activated carbon in the flue gas would form a mercury/sorbent composition.[857] Specifically, a POSITA would have understood that "sorbents" are used in a process called adsorption by which adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas," as per claim element 1(c).

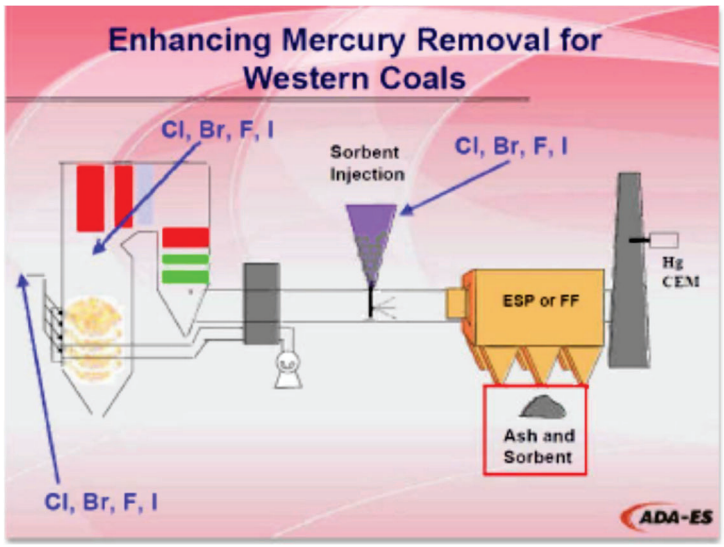
512. In addition, a person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition, because, for example, independent claim 25 of the '114 Patent recites a "mercury/sorbent composition" and its dependent claim 30 recites that "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."[858] Further, through enhanced reactivity between mercury and activated carbon because of the halogens (bromine), a POSITA would have known that the sorbent/halogen complex would have been referred to as a "promoted" sorbent.

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[857] See, e.g., State of the Art, Sections XII.C.3, XII.G.2.
[858] Ex. 1001 ('114 Patent) at Claims 25, 30.

5. Claim 1: Element (1)(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

513. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom describes passing the flue gas through an electrostatic precipitator (ESP) or fabric filter (FF) after the bromine and sorbent injection.[859]

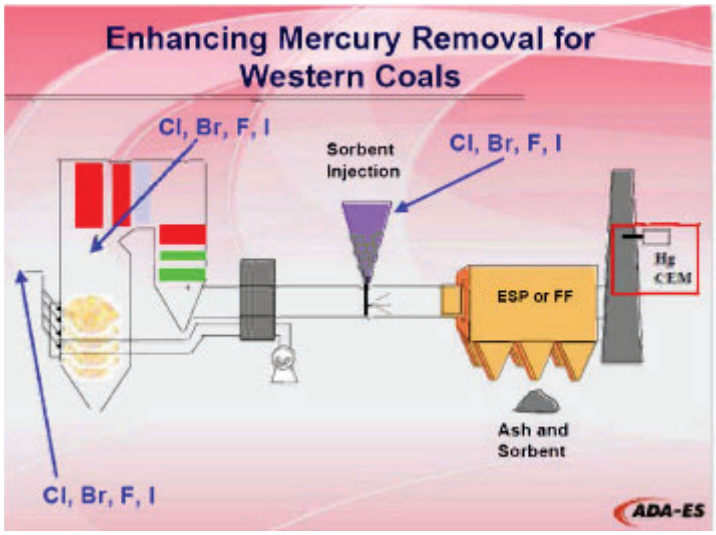


This annotated figure in Sjostrom specifically shows that the sorbent composition would have been removed by the ESP or FF. Further, a POSITA would have understood that it was well-known that the ESP or FF would have removed solid material, including the mercury/sorbent composition.[860] Thus, Sjostrom teaches "separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

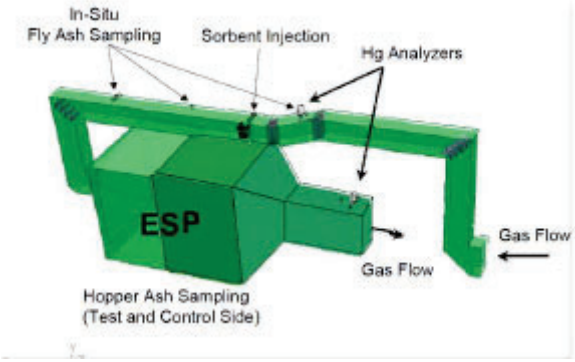
[859] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[860] State of the Art, § XII.B.5.a

6. Claim 1: Element (1)(e)—"monitoring the mercury content of the cleaned gas; and"

514. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom describes passing the treated flue gas through a stack with an attached Hg CEM (continuous emissions monitor) attached.[861]

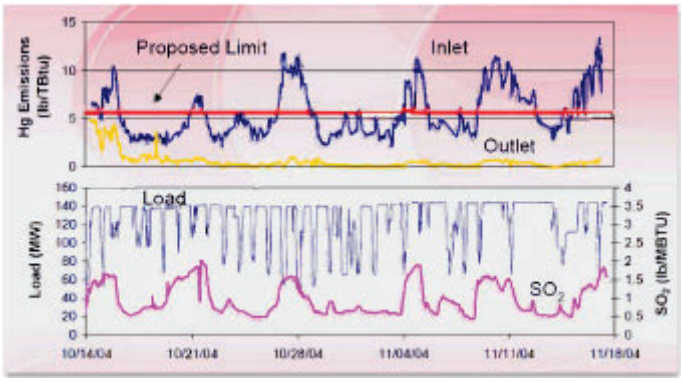


Further, Sjostrom discusses taking Hg measurements at both the inlet and outlet of the ESP as shown below.[862]



[861] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[862] Ex. 1010 (Sjostrom) at 19.

Sjostrom includes the chart showing the Hg emissions as measured at the inlet and outlet of the ESP[863]



Thus, Sjostrom discloses monitoring the mercury content of the cleaned gas.

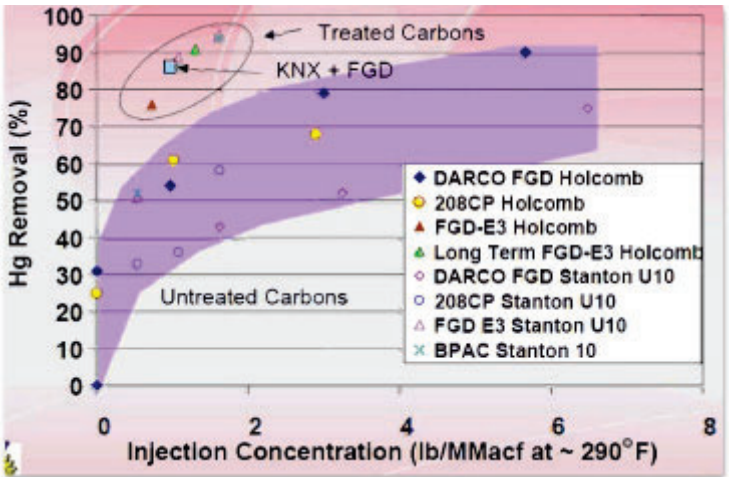
7. Claim 1: Element 1(f)

a. **Element (1)(f)(1)—"controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof,"**

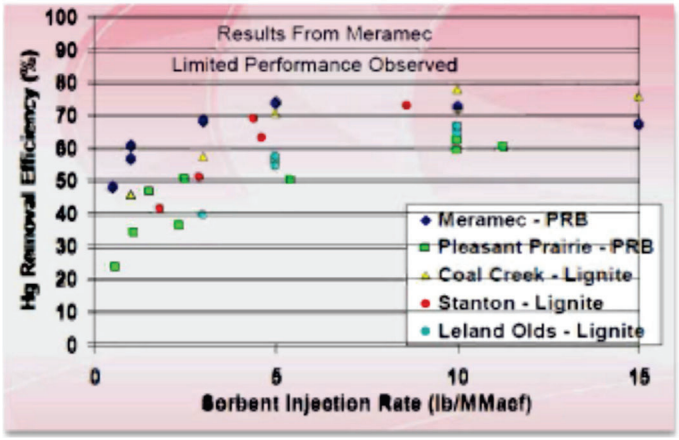
b. **Element (1)(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."**

515. These limitations are disclosed by Sjostrom. Sjostrom includes numerous charts of measured mercury removals (100% – mercury content) for various injection rates of activated-carbon sorbents. For example, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[864]

[863] Ex. 1010 (Sjostrom) at 22.
[864] Ex. 1010 (Sjostrom) at 16.



Similarly, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[865]



516. The fact that there is a graph that has datapoints for different sorbent injection rates (the independent variable) and associated Hg removal percentages (the dependent variable) means that a POSITA would have understood that there is a relationship between the Hg removal % and the sorbent injection rate. Given that,

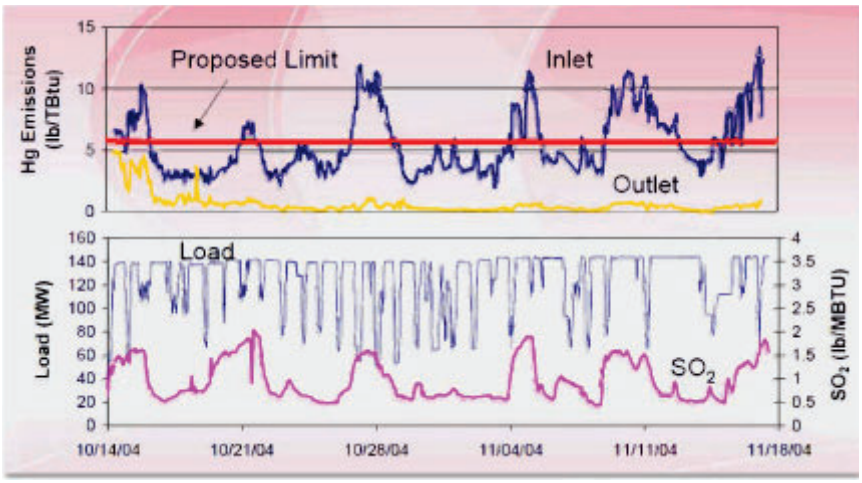
[865] Ex. 1010 (Sjostrom) at 20.

and a target Hg removal rate, a POSITA would have understood that the sorbent injection rate would be adjusted to result in a target removal %.

517. As discussed previously, a POSITA would have known that activated carbon was expensive, especially relative to costs of components such as "Br" in the form of HBr or an aqueous bromide salt solution. Thus, a POSITA would have been motivated to maintain the sorbent injection rate at the minimum level necessary to reach the desired level of mercury emissions. A POSITA viewing the charts of Sjostrom showing mercury removal versus sorbent injection rate would have been motivated to use the charts to control the sorbent injection rate at a level that minimized costs while reaching mercury removal targets. Thus, Sjostrom discloses controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof.

518. The below figure from Sjostrom shows that the testing focused on a "Proposed Limit.[866]

[866] Ex. 1010 (Sjostrom) at 22.



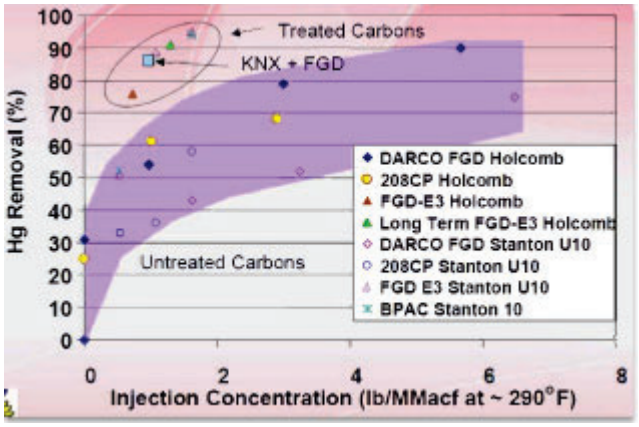
Thus, Sjostrom teaches maintaining the mercury content of the cleaned gas "at or below a desired level" (e.g., the 'Proposed Limit."). A POSITA would have been motivated to control the activated carbon injection rate to reach this desired level while minimizing the amount of activated carbon injected. A POSITA would have understood that injecting too much activated carbon would have increased the costs of the mercury removal process and injecting too little activated carbon may lead to mercury emissions rising above actionable levels. Thus, Sjostrom discloses controlling the system so that the mercury content of the cleaned gas is maintained at or below a desired level.

B. CLAIMS DEPENDING FROM CLAIM 1

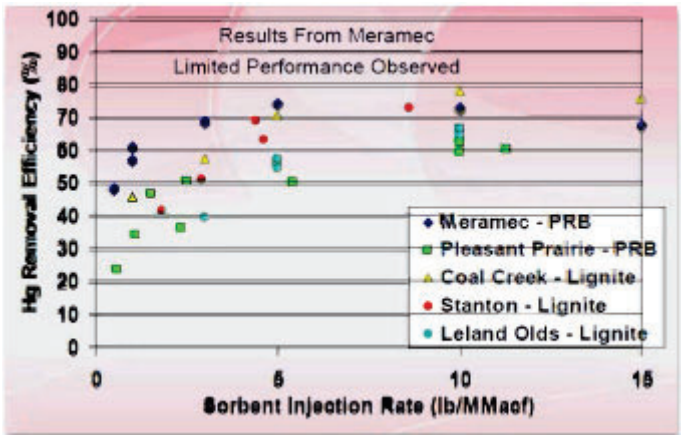
1. Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

519. This limitation is disclosed by Sjostrom. Sjostrom includes numerous charts showing greater than 70 % removal of mercury from the flue gas. For

example, the below chart shows the mercury removal from testing at a plant using the system of Sjostrom.[867]



Similarly, the below chart shows the mercury removal from testing at a plant using the system of Sjostrom.[868]



2. Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."

[867] Ex. 1010 (Sjostrom) at 16.
[868] Ex. 1010 (Sjostrom) at 20.

520. This limitation is disclosed by Sjostrom. A POSITA would understand that the charts discussed in claim 2 above show system demonstrating the removal of the mercury on the sorbent.

3. Claim 4: "The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 2 of the sorbent material."

521. This limitation is obvious over Sjostrom in view of Eckberg. Claim 4 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would lead to an unexpected result from what was already known to one of skill in the art.

522. As described in the State of the Art,[869] it was known that the saturation limit of activated carbon for bromine (i.e., how much bromine the activated carbon can actually adsorb at equilibrium), was up to 31 to 38 grams per 100 grams of activated carbon. Given the residence times in flue gas, and other inefficiencies, a person of ordinary skill in the art would have understood that the actual bromine loaded onto activated carbon would have been less than the saturation limit.

[869] State of the Art, § XII.C.3.

523. A person of ordinary skill in the art would have recognized that there would be sufficient bromine in the flue gas, according to Sjostrom's processes, to provide a ratio of between 1 g to 30 g of bromine per 100 g of activated carbon. For example, Sjostrom teaches mercury-removal results similar to Eckberg, using an injection rate of 1 lb/MMacf activated carbon (FGD) at 290 °F in connection with an unspecified quantity of KNX (bromine).[870] Eckberg discloses a bromine concentration in the flue gas for a nearly identical system was 48 ppm or 50 ppm that results in "81% overall removal" of mercury.[871] A person of ordinary skill in the art would have been motivated to take advantage of the saturation limits of activated carbon, and seek to load the activated carbon with up to nearly its saturation limit, because it was known in the art that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[872]

524. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate to achieve halide promoter on the activated-carbon sorbent from about 1 g to about 30 g.

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[870] Ex. 1010 (Sjostrom) at 16.
[871] Ex. 1011 (Eckberg) at 9, 14.
[872] Ex. 1062 (Crocker) at 2-3.

525. This limitation is also explicitly disclosed in Olson-646. Olson-646 states that "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon"[873] and that "the sorbent comprises from about 1 to about 30 grams promoter per 100 grams of base activated carbon."[874] Accordingly, the claimed ranges were known to be useful for coal combustion applications.

4. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

526. This limitation is disclosed by Sjostrom. As discussed above for claim element 1(b), Sjostrom discloses wherein the combustion chamber comprises added Br_2, HBr, Br–, or a combination thereof. A POSITA would have understood that bromine-containing species was a known halogen or halide promoter. [875]Thus, Sjostrom discloses wherein the combustion chamber comprises the halogen or halide promoter.

5. Claim 6: "The method of claim 1, wherein the coal comprises added Br_2 HBr, Br^-, or a combination thereof added to the coal upstream of the combustion chamber."

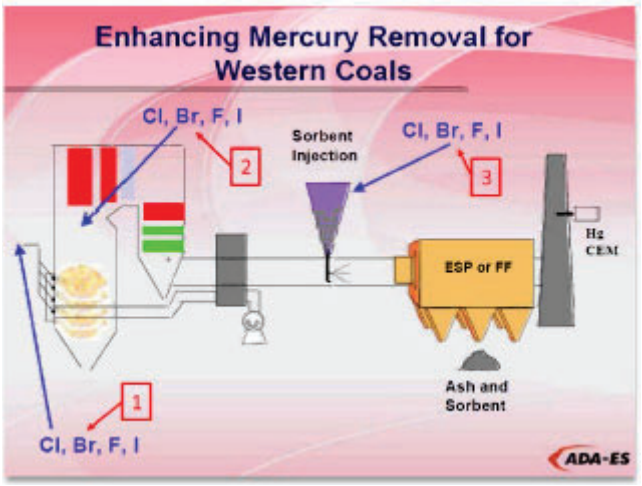
527. This limitation is rendered obvious by Sjostrom and Eckberg. This limitation is the same as one of the elements found in Claim Element 1(b). As discussed above for Claim Element 1(b), Sjostrom renders obvious wherein the coal

873 Ex. 1014 (Olson-646) at ¶ [0023].
874 Ex. 1014 (Olson-646) at ¶ [0014].
875 *See, e.g.,* State of the Art, Sections XII.C.3, XII.G.2.

comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber. As discussed above, Sjostrom in view of Eckberg also renders obvious wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber.

6. Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."

528. This limitation is obvious over Sjostrom in view of Eckberg. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[876] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal power process.[877]

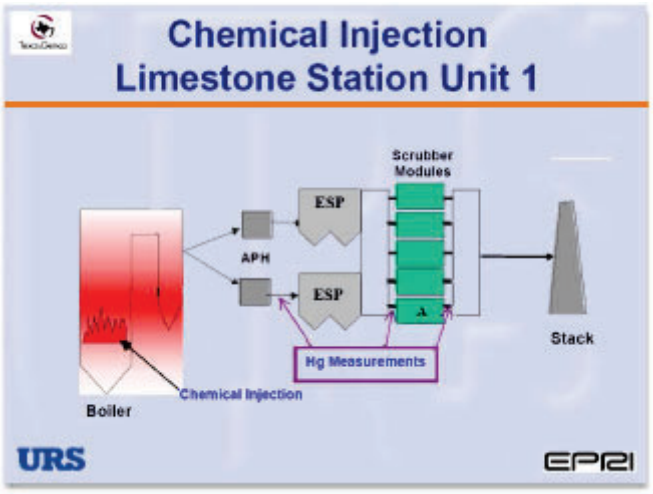


[876] Ex. 1010 (Sjostrom) at 4.
[877] Ex. 1010 (Sjostrom) at 20

529. Addition Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[878] Addition Location 2 of Sjostrom discloses injecting bromine into the boiler.[879] A POSITA would have found it obvious that the "Br" of Sjostrom could be a widely available bromine-containing material, such as HBr or an aqueous solution of a bromide salt, such as $CaBr_2$, for Addition Location 1 and Addition Location 2. Further, Sjostrom teaches the addition of "KNX (Alstom Power)."[880] KNX was a known aqueous solution of a bromide salt additive developed for enhanced mercury control. A POSITA would have found it obvious that an aqueous bromide salt solution, such as $CaBr_2$, would dissociate to form Br^- ions.

530. As shown in the figure below, Eckberg teaches "chemical injection" to the boiler.[881]

[878] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[879] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[880] Ex. 1010 (Sjostrom) at 23.
[881] Ex. 1011 (Eckberg) at 5.



531. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" and "$CaBr_2$ (52 wt%)" into the boiler.[882] Further, Eckberg explains that the $CaBr_2$ salt is injected at a "Liquid Salt Feed Rate (gpm)."[883]

532. A POSITA would have known that the Br injected in Sjostrom would have been in the form of an aqueous bromide salt solution as taught by Eckberg. A POSITA would have understood that at combustion temperatures found within the boiler, at least a portion of the Br^- ions injected at either Addition Location 1 or Addition Location 2 would have evaporated leaving the boiler as HBr in the vapor phase. Once the HBr reached the sorbent injection location, it would make contact with the injected sorbent.

[882] Ex. 1011 (Eckberg) at 9.
[883] Ex. 1011 (Eckberg) at 9.

7. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

533. This limitation is disclosed by Sjostrom. Sjostrom repeatedly discusses the use of activated carbon.[884] Further, Sjostrom includes test results of "Untreated PAC Injection into ESP" for "PRB and Lignite Coals."[885] A POSITA would have known that PAC stood for "powdered activated carbon." Sjostrom also discusses testing done with the injection of "DARCO FGD" sorbent.[886] A POSITA would have known that DARCO FGD was a well-known type of powdered activated-carbon sorbent.[887]

8. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

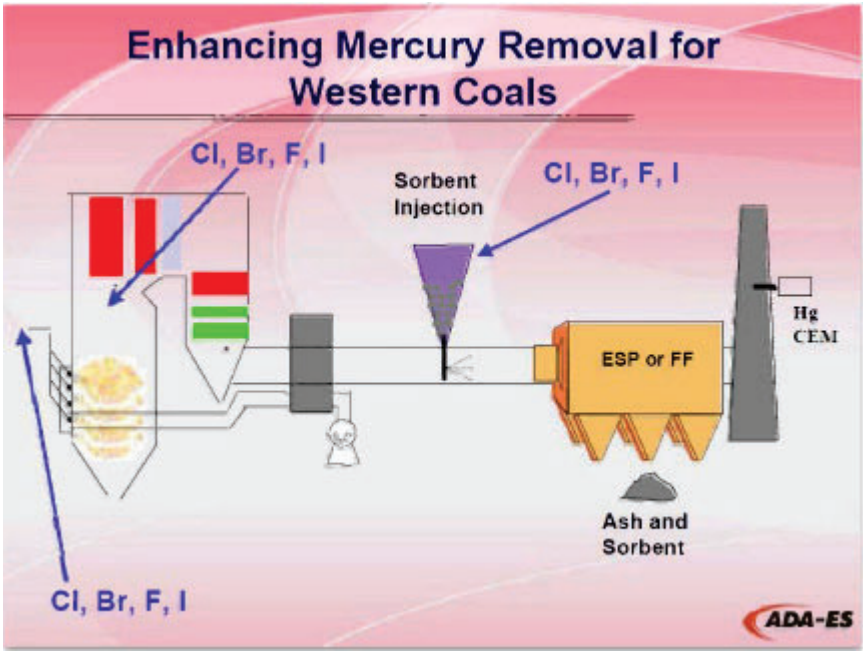
534. This limitation is disclosed by Sjostrom. As discussed for claim element 1(a), Sjostrom discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing flue gas stream.

9. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

535. This limitation is disclosed by Sjostrom. Sjostrom discloses testing performed on the treatment of mercury-containing gas from a coal-fired power plant. A POSITA would have known that the mercury-containing exhaust gas from coal-

[884] Ex. 1010 (Sjostrom) at 10, 20, 34.
[885] Ex. 1010 (Sjostrom) at 20.
[886] Ex. 1010 (Sjostrom) at 15, 16,
[887] See, e.g., State of the Art, Sections XII.C.3, XII.G.2.

fired power plants was commonly referred to as "flue gas." For example, Sjostrom discloses testing on coal-fired power plants according to the following schematic.[888]

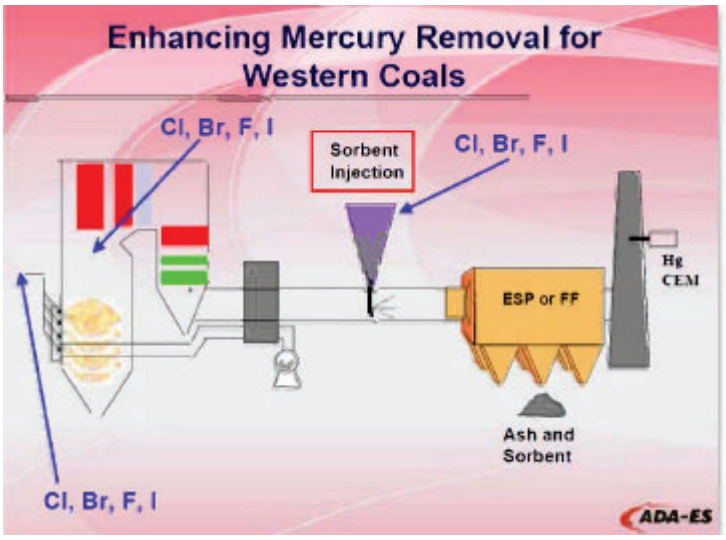


Further, Sjostrom expressly includes discussion of sampling and injection of "Flue Gas Flow."[889]

10. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

536. This limitation is disclosed by Sjostrom As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[890]

[888] Ex. 1010 (Sjostrom) at 4.
[889] Ex. 1010 (Sjostrom) at 19.
[890] Ex. 1010 (Sjostrom) at 4 (annotations in red).



The sorbent injection system of Sjostrom is shown upstream of an ESP or FF.[891] A POSITA would have understood that ESPs and FFs were well-known particulate separators and would be used to collect the mercury-sorbent composition (and thus be downstream of where the mercury-sorbent composition is formed).[892]

11. Claim 20: "The method of claim 1, wherein the combustion chamber comprises added Br_2, HBrg Br^- or a combination thereof."

537. This limitation is disclosed by Sjostrom. As discussed above for element 1(b), Sjostrom discloses wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof.

538. As discussed above for element 1(b), this limitation is also obvious over Sjostrom in view of Eckberg. Sjostrom in view of Eckberg discloses "wherein... the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof."

[891] Ex. 1010 (Sjostrom) at 4.
[892] State of the Art, § XII.B.5.a

C. INDEPENDENT CLAIM 23

539. As shown in the redline below, claim 23 is identical to claim 1, elements preamble, 1(a), 1(b), 1(c), and 1(d), only removing elements 1(e), 1 (f)(1), and 1(0(2).

~~1~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the ~~monitored~~ mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the ~~sorbent composition~~coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or

a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level.

Accordingly, my analysis provided for claim 1 applies to claim 23.

1. Claim 23: Preamble—" A method of separating mercury from a mercury-containing gas, the method comprising:"

540. The language of the preamble of claim 23 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 23.

2. Claim 23: Element 23(a)—" combusting coal in a combustion chamber, to provide the mercury-containing gas,"

541. The language of the claim element 23(a) is identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 23(a).

3. Claim 23: Element 23(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof."

542. The language of claim element 23(b) is identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 23(b).

4. Claim 23: Element 23(c)—" injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

543. The language of claim element 23(c) is identical to the language of claim element 1(c). Accordingly, the explanation I provide above for claim element 1(c) applies equally to claim element 23(c).

5. Claim 23: Element 23(d)—" separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

544. The language of claim element 23(d) is identical to the language of claim element 1(d). Accordingly, the explanation I provide above for claim element 1(d) applies equally to claim element 23(d).

D. INDEPENDENT CLAIM 24

545. As shown in the redlines below, claim 24 is nearly identical to claim 1, with minor changes.

~~1~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the ~~monitored~~ mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the ~~sorbent composition~~coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or

a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level.

Accordingly, my analysis provided for claim 1 applies to claim 24.

1. Claim 24: Preamble—" A method of separating mercury from a mercury-containing gas, the method comprising:"

546. The language of the preamble of claim 24 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 24.

2. Claim 24: Element 24(a)—" combusting coal in a combustion chamber, to provide the mercury-containing gas,"

547. The language of claim element 24(a) is identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 24(a).

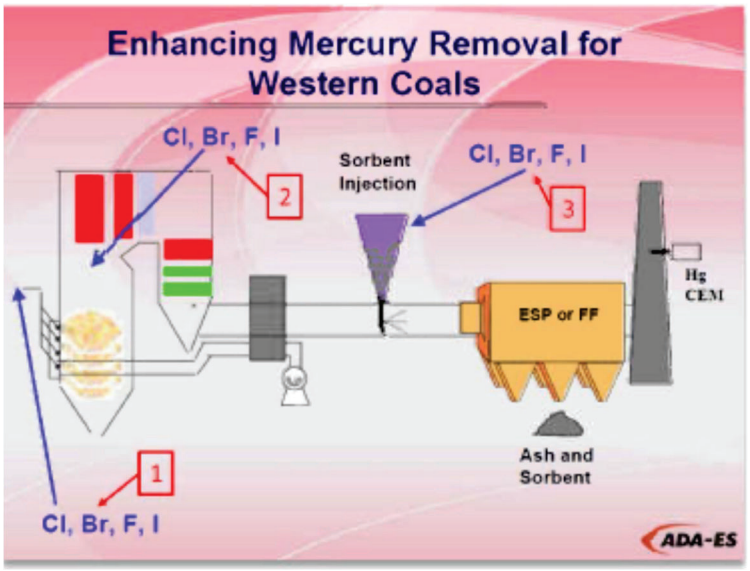
3. Claim 24: Element 24(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof;"

548. The language of claim element 24(b) is identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 24(b).

4. Claim 24: Element 24(c)—" injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;"

549. The language of claim element 24(c) is similar to the language of claim element 1(c), and I refer to my discussion of that claim element. Claim 24(c) adds the requirement that "the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent

composition." This addition is also disclosed because Sjostrom discloses contacting the sorbent material with the halogen in the mercury-containing flue gas. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[893] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal power process.[894]



Addition Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[895] Addition Location 2 of Sjostrom teaches injecting bromine into the boiler.[896]

[893] Ex. 1010 (Sjostrom) at 4.
[894] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[895] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[896] Ex. 1010 (Sjostrom) at 4 (annotations in red).

550. A POSITA would have understood that the bromine injected at Addition Location 1 or Addition Location 2 would have contacted the sorbent in the flue gas at or downstream of the sorbent injection point. A POSITA would also have known that the sorbent and halogen would have reacted to form at least a quantity of promoted sorbent upon contact.[897] Specifically, by 2003, it was well-known that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[898] A POSITA would have known that the introduction of halogens helped remove mercury by increasing the ability of the activated carbon to bind with the mercury. When bromine and carbon come into contact with each other (e.g., upon adsorption as in Sjostrom), a POSITA would have understood that the two react with one another and a promoted sorbent is formed.[899]

5. Claim 24: Element 24(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

551. The language of claim element 24(d) is identical to the language of claim element 1(d). Accordingly, the explanation I provide above for claim element 1(d) applies equally to claim element 24(d).

[897] *See* State of the Art, Sections XII.C.3, XII.G.2.
[898] Ex. 1062 (Crocker) at 2-3.
[899] *See* State of the Art, Sections XII.C.3, XII.G.2.

6. Claim 24: Element 24(e)—"monitoring the mercury content of the cleaned gas; and"

552. The language of claim element 24(e) is identical to the language of claim element 1(e). Accordingly, the explanation I provide above for claim element 1(e) applies equally to claim element 24(e).

7. Claim 24: Element 24(f)(1)—"controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2 HBr, the bromide compound, or a combination thereof, or a combination thereof,"

553. The language of claim element 24(f)(1) is similar to the language of claim element 1(f)(1), and I refer to my discussion of that claim element. Claim 24(f)(1) has the following changes, as compared to claim element 1(f)(1):

> controlling, in response to the monitored mercury content of the cleaned gas,
>
> an injection rate of injecting the sorbent into the mercury-containing gas,
>
> ~~the sorbent composition,~~
>
> a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof,
>
> or a combination thereof,

Claim Element 24(f)(1) is disclosed, for the reasons described above for element 1(f)(1), because Sjostrom discloses adjusting the injection rate of the sorbent into the mercury containing gas.

8. Claim 24: Element 24(f)(2)—" so that the mercury content of the cleaned gas is maintained at or below a desired level."

554. The language of claim element 24(f)(2) is identical to the language of claim element 1(f)(2) Accordingly, the explanation I provide above for claim element 1(f)(2) applies equally to claim element 24(f)(2).

E. INDEPENDENT CLAIM 25.

555. As shown in the redline below, claim 25 is nearly identical to claim 1, with minor changes.

~~1~~25. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, ~~wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br⁻, or a combination thereof,~~ wherein

the coal comprises added Br_2, HBr, ~~Br⁻~~a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, ~~Br⁻~~a bromide compound, or a combination thereof, or

a combination thereof~~,~~,

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~;~~

~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level~~.

Accordingly, my analysis provided for claim 1 applies to claim 25.

1. Claim 25: Preamble—" A method of separating mercury from a mercury-containing gas, the method comprising:"

556. The language of the preamble of claim 25 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 25.

1. Claim 25: Element 25(a)—" combusting coal in a combustion chamber, to provide the mercury-containing gas,"

557. The language of claim element 25(a) is identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 25(a).

2. Claim 25: Element 25(b)—"wherein the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof, or a combination thereof,"

558. The language of claim element 25(b) is similar to the language of claim element 1(b), and I refer to my discussion of that claim element. Claim 25(b) has the following changes, as compared to claim element 1(b):

~~wherein the mercury containing gas comprises a halogen or halide promoter comprising HBr, Br⁻, or a combination thereof~~,

wherein the coal comprises added Br_2, HBr, ~~Br⁻,~~ a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber,

or the combustion chamber comprises added Br_2, HBr, ~~Br⁻,~~ a bromide compound, or a combination thereof,

or a combination thereof;

Unlike claim 1, claim 25 does not recite that "the mercury containing gas comprises a halogen or halogen promoter . . . ." Further, claim 25 recites "a bromide compound" in place of "Br." A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[900] Thus, Sjostrom discloses this element for the same reasons it discloses Claim 1: Element 1(b). To the extent that Sjostrom does not explicitly disclose the "bromide compound" as found in this claim element, Eckberg teaches the addition of an aqueous calcium bromide ($CaBr_2$) solution.

3. Claim 25: Element 25(c)—" injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

559. The language of claim element 25(c) is identical to the language of claim element 1(c). Accordingly, the explanation I provide above for claim element 1(c) applies equally to claim element 25(c).

4. Claim 25: Element 25(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

560. The language of claim element 25(d) is identical to the language of claim element 1(d). Accordingly, the explanation I provide above for claim element 1(d) applies equally to claim element 25(d).

[900] Ex. 1010 (Sjostrom) at 4.

F. CLAIMS DEPENDING FROM CLAIM 25

1. Claim 26: "The method of claim 25, wherein the coal comprises the added Br_2, HBr, the bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber."

561. The language of claim 26 is similar to the language of claim 6, and I refer to my discussion of that claim. Claim 26 has the following changes, as compared to claim 6:

> wherein the coal comprises the added Br_2, HBr, ~~Br~~, the bromide compound or a combination thereof, added to the coal upstream of the combustion chamber

562. A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[901] Thus, Sjostrom renders obvious this element for the same reasons it discloses Claim 6. To the extent that Sjostrom does not explicitly disclose the "bromide compound" as found in this claim element, Eckberg teaches the addition of an aqueous calcium bromide ($CaBr_2$) solution, as described above for element 1(b).

1. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof."

563. The language of claim 27 is similar to the language of claim 20, and I refer to my discussion of that claim. Claim 27 has the following changes, as compared to claim 20:

[901] Ex 1010 (Sjostrom) at 4.

wherein the combustion chamber comprises the added Br_2, HBr, ~~Br,~~ the bromide compound, or a combination thereof."

564. A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[902] Thus, Sjostrom discloses this element for the same reasons it discloses Claim 20. To the extent that Sjostrom does not explicitly disclose the "bromide compound" as found in this claim element, Eckberg teaches the addition of an aqueous calcium bromide ($CaBr_2$) solution, as discussed above for claim element 1(b).

2. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level."

565. The language of claim 28 is similar to the language of claim elements 1(e), 1(0(1), and 1(0(2), and I refer to my discussion of those claim elements. Claim 28 has the following changes, as compared to claim elements 1(e), 1(0(1), and 1(0(2):

> monitoring the mercury content of the cleaned gas; and
>
> contolling in response to the monitored mercury content of the cleane gas.

[902] Ex. 1010 (Sjostrom) at 4.

an injection rate of injecting the sorbent into the mercury-containing gas,

~~the sorbent composition,~~

a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof,

or a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level

Claim 28 is disclosed because Sjostrom discloses monitoring the mercury emissions levels and adjusting the injection rate of the sorbent into the mercury containing gas to maintain the mercury emissions levels at or below a desired level, as discussed above for claim elements 1(e) and l(f).

3. Claim 29: "The method of claim 25, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 2 of the sorbent material."

The language of claim 29 is identical to the language of claim 4. Accordingly, the explanation I provide above for claim 4 applies equally to claim 29.

4. Claim 30: "The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

This limitation is disclosed by Sjostrom. As discussed for claim 7, Sjostrom teaches that the bromide promoter is contacted with the sorbent in vapor form. At least a

quantity of promoted sorbent comprising bromine and sorbent would have formed as a reaction between the sorbent and halogen upon contact. A POSITA would have known that the promoted carbon sorbent injected into the flue gas would contact and adsorb at least a quantity of the mercury in the flue gas. Upon adsorption, the mercury and activated carbon in the flue gas would contact (adhere to) one another to form a mercury/sorbent composition.[903] A POSITA would have understood that this mercury/sorbent composition contains mercury, sorbent, and bromine.

XX. GROUND B: OBVIOUSNESS OF THE '114 PATENT OVER SJOSTROM IN VIEW OF OLSON-646

566. It is my opinion that Sjostrom in view of Olson-646 renders obvious each asserted claim of the '114 Patent.

A. INDEPENDENT CLAIM 1

1. Claim 1: Preamble— "A method of separating mercury from a mercury-containing gas, the method comprising:"

567. As discussed regarding the preamble of claim 1, in Ground A above, the preamble is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

2. Claim 1: Element (1)(a)— "combusting coal in a combustion chamber, to provide the mercury-containing gas,"

[903] *See, e.g.,* State of the Art, Sections XII.C.3, XII.G.2.

568. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

3. Claim 1: Element (1)(b)— "wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof:"

569. As discussed in Ground A above, this limitation is disclosed and/or rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

570. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. To the extent that Sjostrom does not explicitly identify the specific bromine-containing species used, Olson-646 teaches this limitation. Olson-646 "provides a cost-effective way to capture pollutants by utilizing exceptionally reactive halogen/halide promoted carbon sorbents using a bromide (or other halogen/halide) treatment of the carbon, that capture mercury via mercury-sorbent surface reactions, at very short contact times of seconds or less."[904] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor

[904] Ex. 1014 (Olson-646) at ¶ [0043].

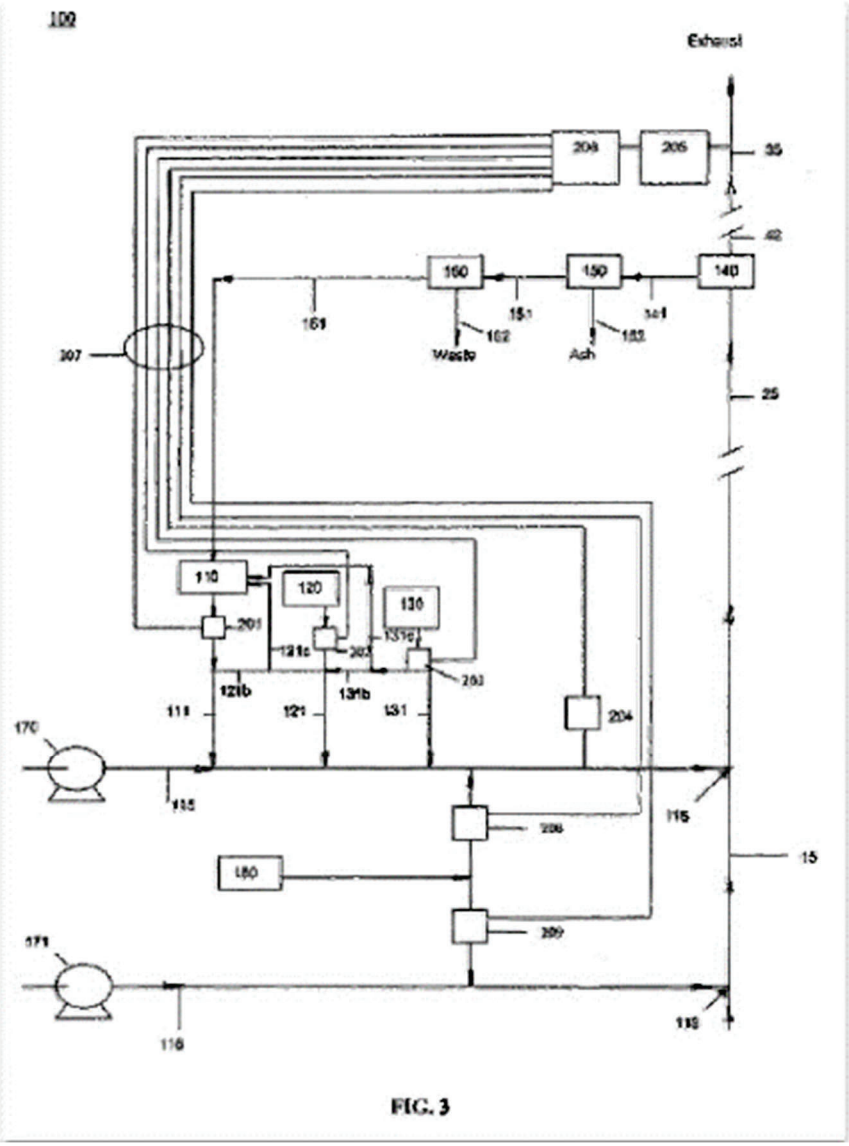
form" that comprises "gaseous HBr or Br_2."[905] As described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom.

4. Claim 1: Element (1)(c)— "injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition:"

571. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

572. To the extent Sjostrom does not explicitly disclose "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition," that limitation is obvious over Sjostrom in view of Olson-646. Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15.[906] The "contaminated flue gas stream" refers to a stream of mercury-containing gas. As shown in Figure 3 of Olson-646 explains that "The halogen/halide . . . contacts and reacts with the base activated carbon prior to injection point 116.[907]

[905] Ex. 1014 (Olson-646) at ¶ [0066].
[906] Ex. 1014 (Olson-646) at ¶ [0061].
[907] Ex. 1014 (Olson-646) at ¶ [0061].



Olson-646 explains that "The halogen/halide ... contacts and reacts with the base activated carbon prior to injection point 116."[908]

573. Olson-646 describes that mercury and activated carbon in the flue gas would react to form a mercury/sorbent composition. Indeed, Olson-646 discloses a promoted activated-carbon sorbent "that capture[s] mercury via mercury-sorbent

[908] Ex. 1014 (Olson-646) at ¶ [0043].

surface reactions,"[909] Olson-646 further describes "AC mercury binding sites" (i.e., sites where mercury contacts the sorbent and forms a mercury/sorbent composition)[910] and shows a mercury-sorbent composition in Figure 2.[911] Thus, Olson-646 discloses "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition."

5. Claim 1: Element (1)(d)— "separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

6. Claim 1: Element (1)(e)— "monitoring the mercury content of the cleaned gas; and"

574. As discussed for Elements 1(d) and 1(e) in Ground A above, these limitations are disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding these elements for Ground A applies equally here.

7. Claim 1: Element 1(f)

a. **Element 1(f)(1)—"controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof,"**

b. **Element 1(f)(2)— "so that the mercury content of the cleaned gas is maintained at or below a desired level."**

[909] Ex. 1014 (Olson-646) at ¶ [0043].
[910] Ex. 1014 (Olson-646) at ¶ [0128].
[911] Ex. 1014 (Olson-646) at Figure 2.

575. As discussed in Ground A above, these limitations are obvious over Sjostrom. My analysis with regards to these elements for Ground A applies equally here.

576. In addition, these limitations are also obvious over Sjostrom in view of Olson-646. After separation, Olson-646 explains that "[t]he reduced mercury 'clean' flue gas stream 142 is then monitored for mercury content by an optional CEM 205, which provides corresponding signals to an optional computer/controller 206 . . . to maintain the mercury concentration in exhaust stream 35 within desired limits, according to control algorithms well known in the art."[912] "CEM" stands for continuous emissions monitor. Even Olson-646 recognizes the corresponding control algorithms were "well known in the art" to keep the mercury content of the cleaned gas "within desired limits" (another term for "desired level").

577. Olson-646 explains that "mercury CEM 205 and flow controllers 201, 202, 203, 208, and 209 are electrically connected via optional lines 207 (or wirelessly) to an optional digital computer (or controller) 206, which receives and processes signals and preferably controls the preparation and injection of promoted carbon sorbent into contaminated flue gas stream 15.[913] Flow controller 201 controls the rate of injection of activated-carbon sorbent, flow controller 202 controls the rate

[912] Ex. 1014 (Olson-646) at Figure 2.
[913] Ex. 1014 (Olson-646) at ¶ [0056], Figure 3.

of injection of halogen promoter, and flow controller 204 discloses the addition of both activated carbon and bromine-containing promoter into the mercury-containing flue gas 15.[914]

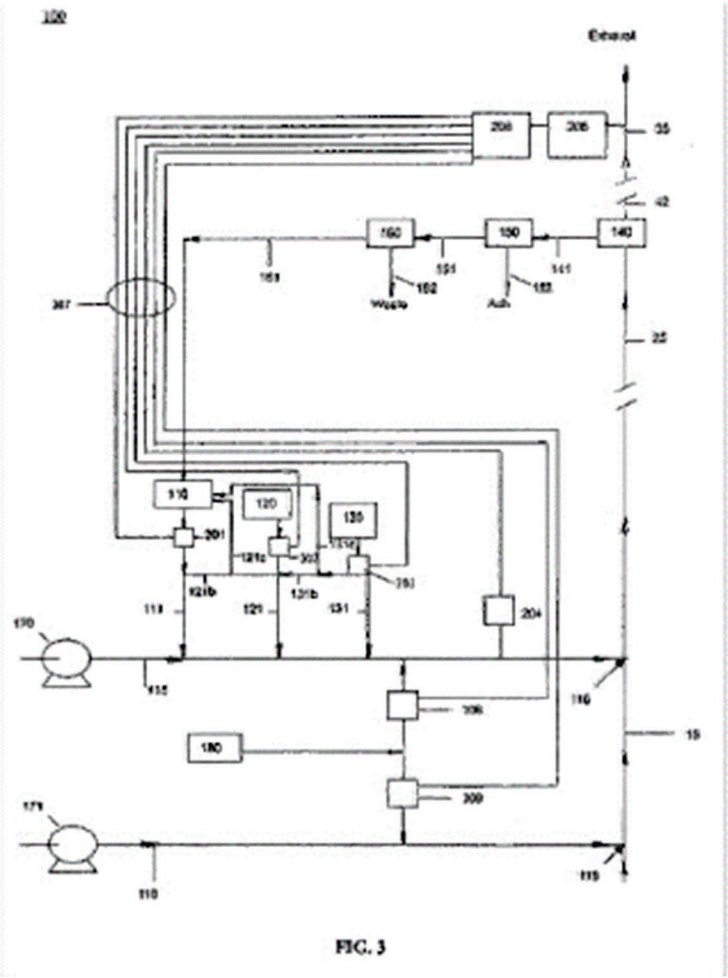


FIG. 3

And as discussed by Olson-646, above, each of these flow controllers and control algorithms were "known in the art," and are used to control the mercury content of the cleaned gas based on feedback signals from mercury measurements.

[914] Ex. 1014 (Olson-646) at ¶ [0058].

578. As discussed in Ground A, including element 1(d), a POSITA viewing the charts of Sjostrom showing mercury removal (Y-axis) versus sorbent injection rate (X-axis) would have been motivated to control the sorbent injection rate at a level that minimized costs while reaching mercury removal targets. To the extent that Sjostrom does not expressly provide operational details about how to control said sorbent injection rate, a POSITA would have been motivated to look to Olson-646 to supply those details. A POSITA would have had a reasonable expectation of success in applying these operational details to Sjostrom because the system of Olson-646 and Sjostrom are substantially similar and are designed to achieve the same goal (e.g., removal of mercury from flue gas). Moreover, the hardware in Olson-646 involves mass-flow controllers and basic feedback logic, each of which were well-known to a person of ordinary skill in the art and routinely used in the power-generation industry. A POSITA would not have had to remove anything from the system of Sjostrom, they merely would have had to apply the teachings of Olson-646 to fill in the missing details, such as flow controllers and valves, to implement the desired control system.

B. CLAIMS DEPENDING FROM CLAIM 1

1. Claims 2 and 3

a. Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

b. Claim 3: "The method of claim 1, comprising removing greater than 70 wt "A) of the mercury in the mercury-containing gas on the sorbent."

579. As discussed in Ground A above, Sjostrom discloses claim 2. My analysis with regards to the disclosure of Sjostrom regarding claim 2 for Ground A applies equally here.

580. In addition, claims 2 and 3 are also obvious over Sjostrom in view of Olson-646. For example, Olson-646 explains that "a method is provided for reducing mercury in flue gas comprising providing a sorbent, injecting the sorbent into a mercury-containing flue gas stream, collecting ***greater than 70 wt-% of the mercury in the flue gas on the sorbent*** to produce a cleaned flue gas, and substantially recovering the sorbent from the cleaned flue gas."[915] Claim 30 of Olson-646 also discloses "comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."[916]

581. A person of skill in the art would have looked to the Olson-646 reference to further understand the mechanisms for the mercury-removal disclosed by Sjostrom. Specifically, a POSITA would have understood that the activated carbon of Sjostrom removed "greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent," as discussed in Ground A above. To the extent that Sjostrom

[915] Ex. 1014 (Olson-646) at ¶ [0022] (emphasis added).
[916] Ex. 1014 (Olson-646) at Claim 30 (emphasis added).

does not explicitly state that the mercury is removed "on the sorbent," Olson-646 provides this explanation. A POSITA would have understood that by using the particular bromine-containing species disclosed in Olson ("HBr or Br_2") as the source of "Br" disclosed in Sjostrom, then "greater than 70 wt % of the mercury in the mercury-containing gas" would have been removed "on the sorbent," as confirmed by Olson-646.

2. Claim 4: "The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material."

582. This limitation is obvious over Sjostrom in view of Olson-646. Claim 4 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would lead to an unexpected result from what was already known to one of skill in the art.

583. As described in the State of the Art,[917] it was known that the saturation limit of activated carbon for bromine (i.e., how much bromine the activated carbon can actually adsorb at equilibrium), was up to 31 to 38 grams per 100 grams of

[917] State of the Art, § XII.C.3.

activated carbon. Given the residence times in flue gas, and other inefficiencies, a person of ordinary skill in the art would have understood that the actual bromine loaded onto activated carbon would have been less than the saturation limit.

584. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate to achieve halide promoter on the activated-carbon sorbent from about 1 g to about 30 g.

585. Olson-646 includes repeated discussion of this ratio of the halogen or halide promoter to the sorbent material in the mercury-containing gas. For example, Olson-646 discloses that in certain embodiments "the sorbent comprises from about 1 to about 30 grams promoter per 100 grams of base activated carbon."[918]

586. A person of skill in the art would have looked to the Olson-646 reference to further understand the relationship between the halogen and activated carbon disclosed by Sjostrom. Specifically, a POSITA would have understood that the activated-carbon sorbent of Sjostrom would have "comprise[d] from about 1 to about 30 grams promoter per 100 grams of base activated carbon" after the activated-carbon sorbent made contact with the "Br" promoter. To the extent that Sjostrom does not explicitly state that the sorbent includes this ratio of promoter:activated carbon, Olson-646 provides this explanation. A POSITA would have understood

[918] Ex. 1014 (Olson-646) at ¶ [0014]; *see also* ¶ [0018] and Claims 3, 17.

that by using the particular bromine-containing species disclosed in Olson ("HBr or Br_2") as the source of "Br" disclosed in Sjostrom, then "the sorbent comprises from about 1 to about 30 grams promoter per 100 grams of base activated carbon."

3. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

587. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

4. Claim 6: "The method of claim 1, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof added to the coal upstream of the combustion chamber."

588. As discussed in Ground A above, this limitation is rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

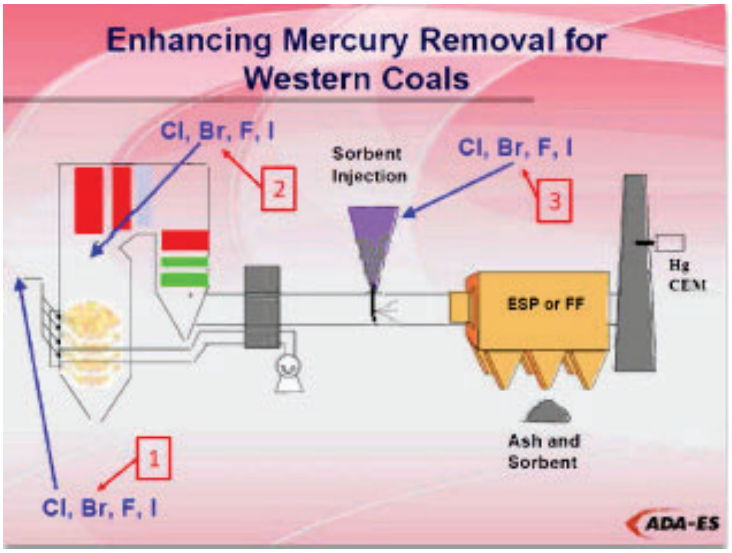
589. In addition, this limitation is also obvious over Sjostrom in view of Olson-646 for the same reasons discussed above for element 1(b). To the extent that Sjostrom does not explicitly identify which particular bromine-containing ("Br" species to use, Olson-646 teaches "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[919] A POSITA desiring to determine the particular "Br" compounds at either location, would have been

[919] Ex. 1014 (Olson-646) at ¶ [0066].

motivated to try HBr or Br_2 (as disclosed in Olson) for the "Br" in Sjostrom, for reasons discussed in the Reasons to Combine section. Indeed, HBr and Br_2 were relatively cheap and widely available sources of bromine. While Olson-646 does not expressly or inherently disclose adding HBr or Br_2 to the coal, it does identify the effectiveness of HBr and Br_2 in promoting activated carbon.

5. Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."

590. This limitation is obvious over Sjostrom in view of Olson-646. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[920] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the process.[921]



[920] Ex. 1010 (Sjostrom) at 4.
[921] Ex. 1010 (Sjostrom) at 4 (annotations in red).

591. Addition Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[922] Addition Location 2 of Sjostrom discloses injecting bromine into the boiler.[923] Although Sjostrom is silent about the form that the bromine should take, a POSITA would have looked to Olson-646 for these details.

592. Specifically, Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[924] A POSITA would have understood that at combustion temperatures found within the boiler any gaseous HBr or Br_2 added at Addition Location 1 or Addition Location 2 of Sjostrom would have remained in the vapor phase. Once the HBr or Br_2 reached the sorbent injection location, it would make contact with the injected sorbent. As described above with respect to Claim 1, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (i.e., the injection of HBr or Br_2) to the system of Sjostrom. While Olson-646 does not disclose adding HBr or Br_2 to the combustion chamber or coal, a POSITA would have looked to Olson to identify the effectiveness of HBr and Br_2 in promoting activated carbon.

[922] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[923] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[924] Ex. 1014 (Olson-646) at ¶ [0066].

6. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

593. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

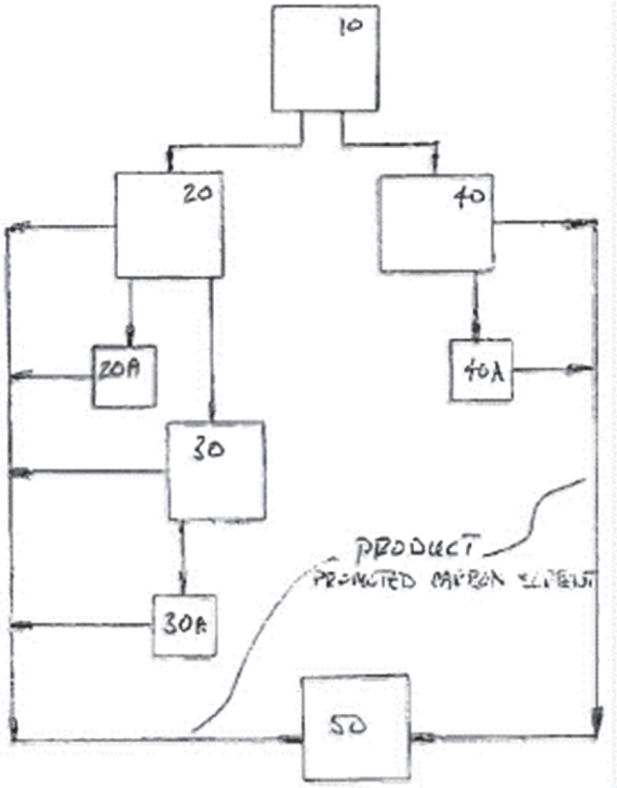


FIG. 1

594. A POSITA would have been motivated to try adding bromine at Injection Points 1 or 2, as taught by Sjostrom, and also adding bromine to the sorbent before injecting at Injection Point 3. as taught by both Sjostrom and Olson-646—particularly for coals with higher native mercury content (or lower native halogen content) in order to further reduce total mercury emissions. In situations where

additional mercury capture was required, a POSITA would have been motivated to inject, or at least try injecting, "Br" at Addition Location 1 or 2 while adding a treated activated-carbon sorbent to the flue gas downstream of the boiler (e.g., at Addition Location 3). A POSITA would have known that this approach would have increased overall mercury capture, albeit at an increased cost compared to using bromine only at Injection Points 1 and 2.

7. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

595. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

8. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

596. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

9. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

597. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

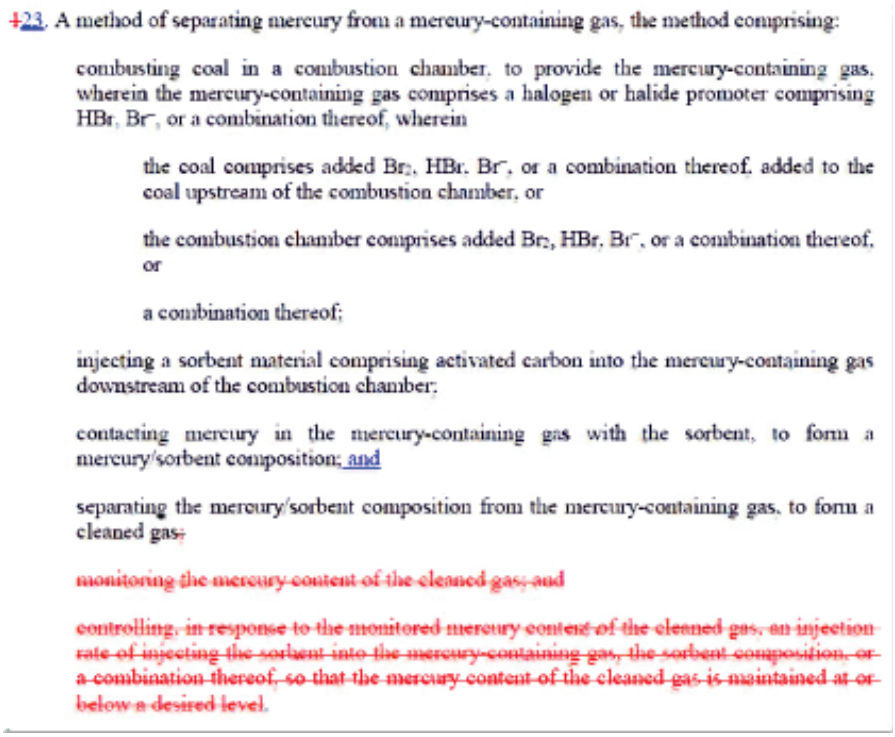
10. Claim 20: "The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof."

598. As discussed in Ground A above, this limitation is rendered obvious by Sjostrom. My analysis with regards to these claims for Ground A applies equally here.

599. In addition, these limitations are also obvious over Sjostrom in view of Olson-646. As described above, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom, as discussed in the Reasons to Combine section.

C. INDEPENDENT CLAIM 23

600. As shown in the redline below, claim 23 is identical to claim 1, elements preamble, 1(a), 1(b), 1(c), and 1(d), only removing elements 1(e), 1(f)(1), and 1(f)(2).



+23. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.~~

Accordingly, my analysis provided for claim 1 applies to claim 23.

1. Claim 23: Preamble—" A method of separating mercury from a mercury-containing gas, the method comprising:"

601. The language of the preamble of claim 23 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 23.

2. Claim 23: Element 23(a)— "combusting coal in a combustion chamber, to provide the mercury-containing gas:

602. The language of the claim element 23(a) is identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 23(a).

3. Claim 23: Element 23(b)— "wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof;"

603. The language of claim element 23(b) is identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 23(b).

4. Claim 23: Element 23(c)— "injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

604. The language of claim element 23(c) is identical to the language of claim element 1(c). Accordingly, the explanation I provide above for claim element 1(c) applies equally to claim element 23(c).

5. Claim 23: Element 23(d)— "separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

605. The language of claim element 23(d) is identical to the language of claim element 1(d). Accordingly, the explanation I provide above for claim element 1(d) applies equally to claim element 23(d).

D. INDEPENDENT CLAIM 24

606. As shown in the redlines below, claim 24 is nearly identical to claim 1, with minor changes.

~~1~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the ~~monitored~~ mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the ~~sorbent composition~~coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or

a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level.

Accordingly, my analysis provided for claim 1 applies to claim 24.

1. Claim 24: Preamble— "A method of separating mercury from a mercury-containing gas, the method comprising:"

607. The language of the preamble of claim 24 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 24.

2. Claim 24: Element 24(a)— "combusting coal in a combustion chamber, to provide the mercury-containing gas,"

608. The language of claim element 24(a) is identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 24(a).

3. Claim 24: Element 24(b)— "wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof;"

609. The language of claim element 24(b) is identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 24(b).

4. Claim 24: Element 24(c)— "injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;"

610. The language of claim element 24(c) is similar to the language of claim element 1(c), and I refer to my discussion of that claim element. Claim 24(c) adds the requirement that "the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent." As discussed in Ground

A above, this additional limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

611. This additional limitation is also disclosed by Olson-646. When bromine and carbon come into contact with each other, as in Sjostrom and Olson-646, a POSITA would have understood that this is a disclosure that they react to form a promoted sorbent.[925] For example, Olson-646 explains that " Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[926]

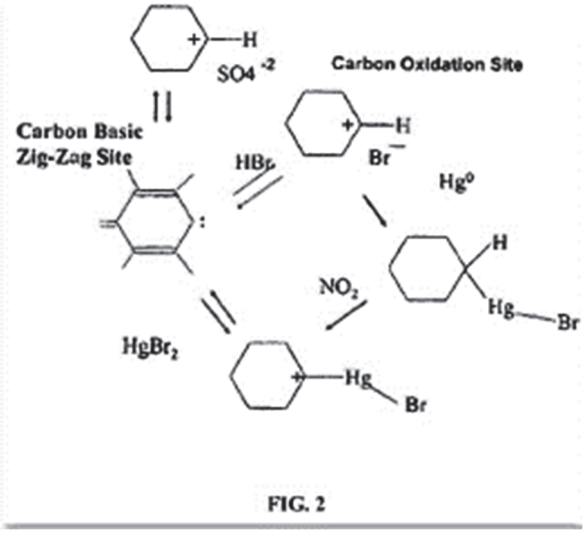


FIG. 2

Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[927] Olson-646 teaches that the reaction may take place at "a

[925] *See* State of the Art, Sections XII.C.3, XII.G.2.
[926] Ex. 1014 (Olson-646) at ¶ [0054].
[927] Ex. 1014 (Olson-646) at ¶ [0054] (emphasis added).

carbene species on the edge of the graphene sheet structures of the carbon."[928] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[929] Figure 2 of Olson-646 shows that once the bromine/activated carbon complex contacts mercury, it chemically reacts with (e.g., adsorbs) the mercury.

612. A person of skill in the art would have looked to the Olson-646 reference to further understand the relationship between the halogen and activated carbon disclosed by Sjostrom. Specifically, a POSITA would have understood that the activated-carbon sorbent of Sjostrom would have made contact and reacted with the "Br" promoter. To the extent that Sjostrom does not explicitly state that the sorbent and halogen make contact, Olson-646 provides this explanation. A POSITA would have understood that by using the particular bromine-containing species disclosed in Olson ("HBr or Br_2") as the source of "Br" disclosed in Sjostrom, then "the sorbent material injected into the mercury-containing gas is a promoted sorbent obtained by contacting a base sorbent with another halogen or halide promoter."

[928] Ex. 1014 (Olson-646) at ¶ [0054].
[929] Ex. 1014 (Olson-646) at ¶ [0054].

5. Claim 24: Element 24(d)— "separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

613. The language of claim element 24(d) is identical to the language of claim element 1(d). Accordingly, the explanation I provide above for claim element 1(d) applies equally to claim element 24(d).

6. Claim 24: Element 24(e)— "monitoring the mercury content of the cleaned gas; and"

614. The language of claim element 24(e) is identical to the language of claim element 1(e). Accordingly, the explanation I provide above for claim element 1(e) applies equally to claim element 24(e).

7. Claim 24: Element 24(f)(1)— "controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof,"

615. The language of claim element 24(f)(1) is similar to the language of claim element 1(f)(1), and I refer to my discussion of that claim element. Claim 24(f)(1) has the following changes, as compared to claim element 1(f)(1):

controlling, in response to the monitored mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

~~the sorbent composition,~~

a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof,

or a combination thereof,

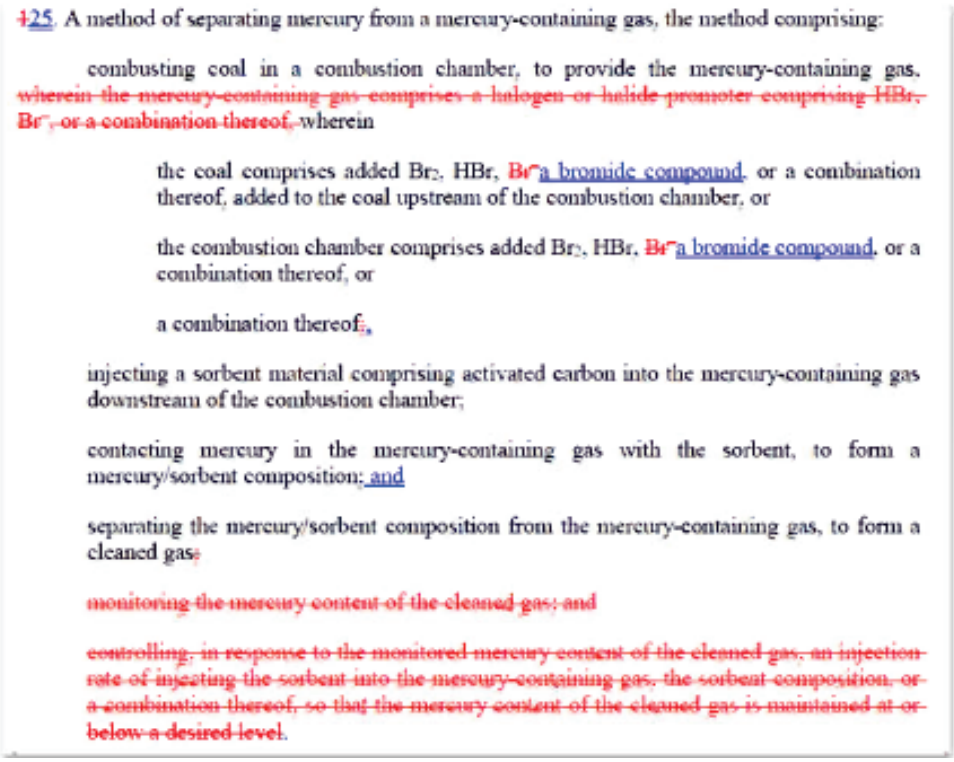
Claim Element 24(f)(1) is disclosed because both Sjostrom and Olson-646 disclose adjusting the injection rate of the sorbent into the mercury containing gas, as I describe for claim element 1(f)(1).

8. Claim 24: Element 24(f)(2)— "so that the mercury content of the cleaned gas is maintained at or below a desired level."

616. The language of claim element 24(f)(2) is identical to the language of claim element 1(f)(2). Accordingly, the explanation I provide above for claim element 1(f)(2) applies equally to claim element 24(f)(2).

E. INDEPENDENT CLAIM 25.

617. As shown in the redline below, claim 25 is nearly identical to claim 1, with minor changes.



~~125~~. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, ~~wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br⁻, or a combination thereof,~~ wherein

the coal comprises added Br_2, HBr, ~~Br⁻~~a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, ~~Br⁻~~a bromide compound, or a combination thereof, or

a combination thereof~~:~~,

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~:~~

~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level~~.

Accordingly, my analysis provided for claim 1 applies to claim 25.

1. Claim 25: Preamble— "A method of separating mercury from a mercury-containing gas, the method comprising:"

618. The language of the preamble of claim 25 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 25.

2. Claim 25: Element 25(a)— "combusting coal in a combustion chamber, to provide the mercury-containing gas,"

619. The language of claim element 25(a) is identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 25(a).

3. Claim 25: Element 25(b)— "wherein the coal comprises added Br_2 HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, a bromide compound, or a combination thereof, or a combination thereof,"

620. The language of claim element 25(b) is similar to the language of claim element 1(b), and I refer to my discussion of that claim element. Claim 25(b) has the following changes, as compared to claim element 1(b):

~~wherein the mercury containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof~~,

wherein the coal comprises added Br_2, HBr, ~~Br^-,~~ a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber,

or the combustion chamber comprises added Br_2, HBr, ~~Br^-,~~ a bromide compound, or a combination thereof,

or a combination thereof;

Unlike claim 1, claim 25 does not recite that "the mercury containing gas comprises a halogen or halogen promoter . . ." Further, claim 25 recites "a bromide compound" in place of "Br." A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[930] Furthermore, as described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom.

[930] Ex. 1010 (Sjostrom) at 4.

4. Claim 25: Element 25(c)— "injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

621. The language of claim element 25(c) is identical to the language of claim element 1(c). Accordingly, the explanation I provide above for claim element 1(c) applies equally to claim element 25(c).

5. Claim 25: Element 25(d)— "separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

622. The language of claim element 25(d) is identical to the language of claim element 1(d). Accordingly, the explanation I provide above for claim element 1(d) applies equally to claim element 25(d).

F. CLAIMS DEPENDING FROM CLAIM 25

1. Claim 26: "The method of claim 25, wherein the coal comprises the added Br_2, HBr, the bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber."

623. The language of claim 26 is similar to the language of claim 6, and I refer to my discussion of that claim. Claim 26 has the following changes, as compared to claim 6:

> wherein the coal comprises the added Br_2, HBr, ~~Br⁻,~~ the bromide compound or a combination thereof, added to the coal upstream of the combustion chamber

624. A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[931] Thus, Sjostrom discloses this element for the same reasons it discloses Claim 6.

625. Furthermore, as described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom. While Olson-646 does not disclose adding HBr or Br_2 to the combustion chamber or coal, it does describe the effectiveness of HBr and Br_2 in promoting activated carbon.

2. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof."

626. The language of claim 27 is similar to the language of claim 20, and I refer to my discussion of that claim. Claim 27 has the following changes, as compared to claim 20:

> wherein the combustion chamber comprises the added Br_2, HBr, ~~Br,~~ the bromide compound, or a combination thereof."

627. A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[932] Thus, Sjostrom discloses this element for the same reasons it discloses Claim 20.

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[931] Ex. 1010 (Sjostrom) at 4.
[932] Ex. 1010 (Sjostrom) at 4.

628. Furthermore, as described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom. While Olson-646 does not disclose adding HBr or Br_2 to the combustion chamber or coal, it does describe the effectiveness of HBr and Br_2 in promoting activated carbon.

3. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level."

629. The language of claim 28 is similar to the language of claim elements 1(e), 1(f)(1), and 1(f)(2), and I refer to my discussion of those claim elements. Claim 28 has the following changes, as compared to claim elements 1(e), 1(f)(1), and 1(f)(2):

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

~~the sorbent composition,~~

a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof,

or a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level.

Claim 28 is disclosed because Sjostrom discloses monitoring the mercury emissions levels and adjusting the injection rate of the sorbent into the mercury containing gas to maintain the mercury emissions levels at or below a desired level, as discussed above for Elements 1(e) and 1(f).

4. Claim 29: "The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."

630. This limitation is obvious over Sjostrom in view of Olson-646. Olson-646 includes repeated discussion of this ratio of the halogen or halide promoter to the sorbent material. For example, Olson-646 discusses embodiments wherein "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon."[933] This limitation also appears repeatedly in the claims of Olson-646.[934]

[933] Ex. 1014 (Olson-646) at ¶ [0023].
[934] Ex. 1014 (Olson-646) at Claims 3, 17, 37, 47.

Olson-646 also discloses an embodiment wherein "the injected sorbent is prepared in-flight by reacting an activated carbon and a promoter within a pneumatic transport line from which the reaction product is injected to the mercury-containing flue gas stream."[935] In that embodiment, Olson-646 explains that "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon."[936]

631. A person of skill in the art would have looked to the Olson-646 reference to provide the implementation details for the system of Sjostrom. Specifically, a POSITA would have been motivated to find the type of "Br" for injection and the relative rates of addition for both activated carbon and "Br" for optimum mercury removal. To the extent that Sjostrom does not explicitly state that the ratio of promoter: activated carbon addition, Olson-646 provides this explanation.

632. Claim 29 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would lead to an unexpected result from what was already known to one of skill in the art.

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[935] Ex. 1014 (Olson-646) at If [0027].
[936] Ex. 1014 (Olson-646) at ¶ [0027].

633. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to achieve about 1 g to about 30 g of halide promoter per 100 g of carbon sorbent in the flue gas.

5. Claim 30: "The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

634. As discussed in Ground A above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground A applies equally here.

635. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. For example, Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[937]

[937] Ex. 1014 (Olson-646) at ¶ [0054], Figure 2.

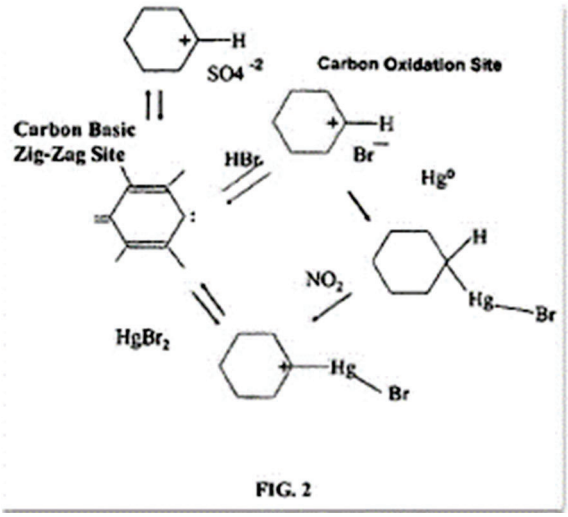


FIG. 2

Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[938] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[939] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[940] Figure 2 of Olson-646, annotated below, shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury.

[938] Ex. 1014 (Olson-646) at ¶ [0054].
[939] Ex. 1014 (Olson-646) at ¶ [0054].
[940] Ex. 1014 (Olson-646) at ¶ [0054].

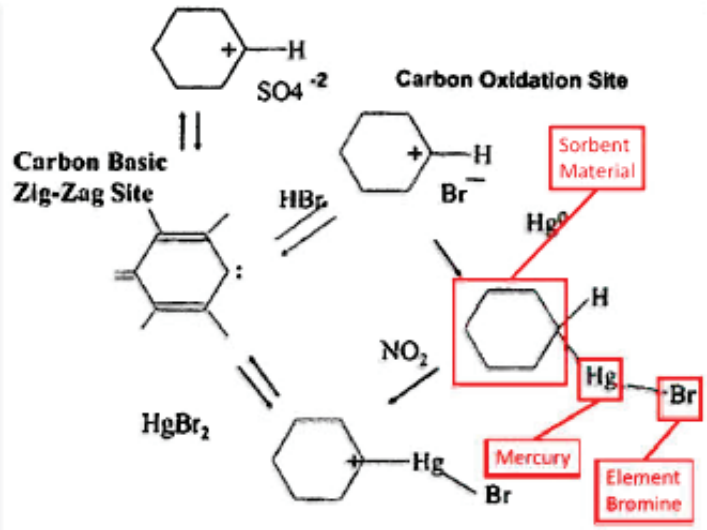


FIG. 2

A person of skill in the art would have looked to the Olson-646 reference to further understand the reaction and relationship already occurring between the halogen, activated carbon, and mercury disclosed by Sjostrom. Specifically, a POSITA would have understood that Sjostrom discloses a flue gas that would contain "Br", mercury, and activated carbon.[941] To the extent that Sjostrom does not explicitly explain what occurs when these three components meet in the flue gas, Olson-646 provides this explanation.

[941] Ex. 1010 (Sjostrom) at 4.

XXI. GROUND C: ANTICIPATION AND OBVIOUSNESS OF THE '114 PATENT BY DOWNS-BOILER

636. It is my opinion that Downs-Boiler anticipates or renders obvious each asserted claim of the '114 Patent. I start my analysis below with claim 25 because it has the fewest limitations. I then discuss claims dependent from claim 25 and follow with claim 23 which repeats many of the limitations of claim 25. In the subsections below, I rely on the disclosure of Downs-Boiler. The material I rely on was also disclosed and supported by Downs-Boiler-Provisional, so parallel citations to Downs-Boiler-Provisional are also included.

A. INDEPENDENT CLAIM 25

1. Claim 25: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

637. Downs-Boiler discloses the preamble. The title of Downs-Boiler is "Bromine Addition for the Improved Removal of Mercury from Flue Gas.[942] Flue gas is an example of a mercury-containing gas, and "removal of mercury" refers to separating the mercury from a mercury-containing gas. Downs-Boiler repeatedly characterizes the disclosed process as for removing *(i.e.,* separating) mercury from flue gas (i.e., a mercury-containing gas):

> [T]he use of bromine-containing compounds, added to the coal, or to the boiler combustion furnace, are significantly more effective than chlorine-containing compounds in enhancing the

[942] Ex. 1006 (Downs-Boiler) at Title; Ex. 1007 (Downs-Boiler-Provisional) at Title.

> oxidation of mercury, thereby enhancing the overall removal of mercury in downstream pollution control devices.[943]

Claim 1 of Downs-Boiler also recites a similar preamble: "1. A method of removing a portion of the elemental mercury in a flue gas"[944] The removal of mercury from the flue gas as described by Downs-Boiler is by separating the mercury along with a sorbent:[945]

> The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often been successfully applied for the *separation and removal* of trace quantities of undesirable components.

Downs-Boiler characterizes its disclosed "invention" as "a cost-effective method of removing elemental mercury from coal combustion flue gases."[946]

2. Claim 25: Element 25(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas,"

638. Downs-Boiler discloses this claim element. The primary application taught by Downs-Boiler is with "[c]oal-fired utility boilers [that] are a known major

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[943] Ex. 1006 (Downs-Boiler) ¶ [0007]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [0013].

[944] Ex. 1006 (Downs-Boiler) at Claim 1; see also Ex. 1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising.").

[945] Ex. 1006 (Downs-Boiler) ¶ [0004] (emphasis added); Ex. 1007 (Downs-Boiler-Provisional) IT [005].

[946] Ex. 1006 (Downs-Boiler) ¶ [0018]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [021].

source of anthropogenic mercury emissions in the United States.[947] Downs-Boiler illustrates a conventional coal-fired utility boiler used for the purpose of combusting coal, as represented by the arrow into combustion chamber 14. Representative Figure 4 is reproduced below:[948]

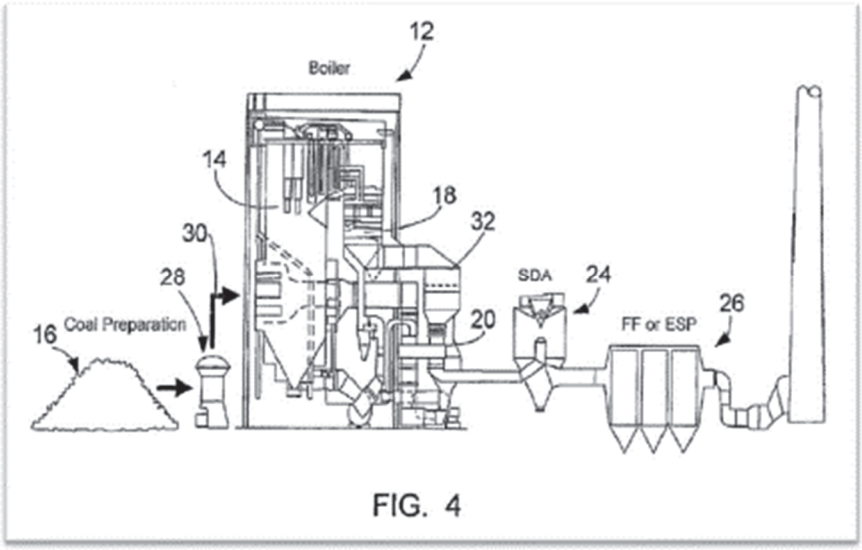


FIG. 4

639. Downs-Boiler goes on to describe such a combustion of coal together with an added bromine-containing reagent, which occurs within combustion chamber 14, as illustrated in Figures 4-6:[949]

> A bromine containing reagent 10 is *added to the boiler* 12 combustion furnace 14, either directly or by *premixing with the incoming coal* 16. Bromine species released *during the combustion process* enhance the oxidation of *mercury as the combustion gases* pass through the furnace 14 and, in particular,

[947] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [002].
[948] Ex. 1006 (Downs-Boiler) ¶ [0007], Figures 4; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [009], Figures 4.
[949] Ex. 1006 (Downs-Boiler) ¶ [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018].

through the *cooler sections of the boiler* convection pass 18 and combustion air preheater 20.

Downs-Boiler describes combusting common ranks of coal used by the electric utility industry and, specifically, that "the coal-fired boiler fuel 16 may include bituminous, subbituminous, and lignite coals and blends, thereof."[950] Finally, Downs-Boiler explicitly describes that "[m]ercury appears in coal combustion flue gases in both solid and gas phases."[951] This flue gas referred to by Downs-Boiler is an example of a mercury-containing gas, and was generated from the combustion of coal.

3. Claim 25: Element 25(b)—"wherein the coal comprises added Br_2 HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, a bromide compound, or a combination thereof, or a combination thereof,"

640. Downs-Boiler discloses this claim element. Although the claim only requires one to be shown, Downs-Boiler discloses both: 1) adding Br_2, HBr, and/or a bromide compound to the coal upstream of the combustion chamber, and 2) adding Br_2, HBr, and/or a bromide compound to the combustion chamber; as well as the combination of the two.

[950] Ex. 1006 (Downs-Boiler) ¶ [0020]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0023].
[951] Ex. 1006 (Downs-Boiler) ¶ [0002] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [003].

641. First, Downs-Boiler discloses Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber. Downs-Boiler explains that the bromine-containing reagent may comprise, "but is not limited to, ***alkali metal*** and ***alkaline earth metal bromides, hydrogen bromide (HBr)*** or ***bromine (Br_2).***"[952] Downs-Boiler also specifically discloses ***calcium bromide ($CaBr_2$)*** as another suitable bromide compound for use as the bromine-containing reagent.[953]

642. This bromine-containing reagent is applied to the coal upstream of the combustion chamber. Downs-Boiler teaches that a "bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16."[954] According to the preferred embodiment of Downs-Boiler, ***"an aqueous solution*** of calcium bromide is sprayed ***onto the crushed coal 16*** before the coal 16 is pulverized for combustion. The aqueous solution is easily handled and metered *onto the coal 16*" such that the *"coal pulverizers 28 intimately mix the bromide reagent 10 with the coal 16,* and the pulverized coal conveying system 30 to the several coal burners (not shown) ensures an even distribution of the reagent 10

[952] Ex. 1006 (Downs-Boiler) 41] [0021] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) 'll [0024].
[953] Ex. 1006 (Downs-Boiler) 11 [0018-19] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) l] [0021-22].
[954] Ex. 1006 (Downs-Boiler) 11 [0015]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0018].

across the boiler furnace 14."[955] Thus, upstream of the combustion chamber, such as in the coal pulverizers and the pulverized coal conveying system, at least one or a combination of Br_2, HBr, and a bromide compound (e.g., calcium bromide ($CaBr_2$)) has been added on the coal.

643. Second, Downs-Boiler discloses "the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof" As described above—where the bromine-containing reagent is disclosed as added to the coal and/or the coal conveying system—this further discloses that the combustion chamber comprises added bromine-containing reagent *(e.g.,* Br_2, HBr, a bromide compound, or a combination thereof). As explained by Downs-Boiler, as a result of adding the bromine-containing reagent to the coal and/or the coal conveying system, the "***[b]romine species released during the combustion process*** enhance the oxidation of mercury as the combustion gases pass ***through the furnace 14***."[956] That the bromine-containing reagent is "sprayed on the crushed coal 16 before the coal is pulverizedfor *combustion"* additionally "ensures even distribution of the [bromine-

[955] Ex. 1006 (Downs-Boiler) ¶ [0019], Figure 2; *see also* Ex. 1007 (Downs-Boiler-Provisional) III [0022], Figure 2.

[956] Ex. 1006 (Downs-Boiler) 11 [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018].

containing] reagent 10 ***across the boiler furnace*** *(i.e.,* in the combustion chamber).[957]

644. Downs-Boiler also discloses introduction of Br_2, HBr, and/or a bromide compound *(i.e.,* the bromine-containing reagent) directly into the combustion chamber. Downs-Boiler teaches that a "bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16"[958]. Downs-Boiler describes that the inventors successfully tested direct introduction of the bromine-containing reagent—specifically, a bromide compound of calcium bromide ($CaBr_2$)—"injected into the combustion chamber 14 through a coal burner."[959] Downs-Boiler further recognizes that "the bromine-containing reagent 10 may be fed to the boiler combustion zone 14 in gaseous, liquid, or solid form."[960] Thus, the combustion chamber comprises at least one or a combination of Br_2, HBr, and a bromide compound *(e.g.,* calcium bromide ($CaBr_2$)).

645. Third, Downs-Boiler discloses adding a bromine-containing reagent to both the coal and the combustion chamber. As described above, Downs-Boiler

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[957] Ex. 1006 (Downs-Boiler) ¶ [0019] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0022].
[958] Ex. 1006 (Downs-Boiler) ¶ [0015]; see also Ex. 1007 (Downs-Boiler-Provisional) 11 [0018].
[959] Ex. 1006 (Downs-Boiler) 11 [0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0021].
[960] Ex. 1006 (Downs-Boiler) ¶ [0022]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0025].

describes applying the bromine-containing reagent to the coal upstream of the combustion chamber in such a way that added Br_2, HBr, and/or a bromide compound *(e.g.,* calcium bromide ($CaBr_2$)) is both on the coal *and* in the combustion chamber.

646. Furthermore, as illustrated in Figure 2, reproduced below as annotated, Downs-Boiler illustrates that the bromine-containing reagent may be introduced "to addition points A, B, C" including "coal preparation," "the pulverized coal conveying system 30," and "the boiler furnace 14."[961]

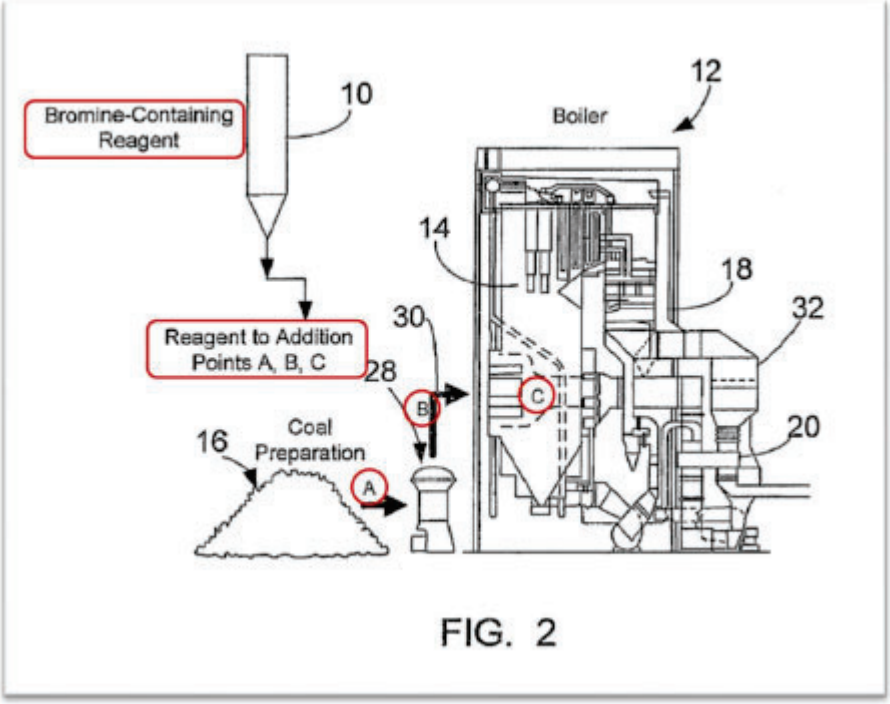


FIG. 2

Downs-Boiler in no way restricts simultaneous introduction to each of points A, B, and C. Rather, as described above, Downs-Boiler invites, if not encourages,

[961] Ex. 1006 (Downs-Boiler) ¶ [0019], Figure 2 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0022], Figure 2.

simultaneous introduction to each of points A, B, and C or some combination of A/B and C to "intimately mix the bromide reagent 10 with the coal" so as to achieve a more "even distribution of the reagent 10 across the boiler furnace 14."[962] Accordingly, Downs-Boiler discloses each and every limitation of Claim Element 25(b).

4. Claim 25: Element 25(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

647. Downs-Boiler discloses this claim element. Downs-Boiler discloses injecting activated carbon into a mercury-containing flue gas downstream of the combustion chamber and contacting mercury with the sorbent to form a mercury/sorbent composition.

a. Claim 25: Element 25(c)(1)—"Injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber"

648. Downs-Boiler discloses that injecting a sorbent material comprising activated carbon, referring to the example of "powdered activated carbon (PAC)."[963] Downs-Boiler explains that the use of a conventional PAC injection process is

[962] Ex. 1006 (Downs-Boiler) ¶ [0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0022].
[963] Ex. 1006 (Downs-Boiler) ¶ [0025]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0028].

improved by the addition of bromine, in that the bromine-containing reagent "enhances the removal of mercury across a ***PAC injection*** process."[964] Downs-Boiler repeats in other places that the bromine-containing reagent saves costs by making more efficient use of the activated-carbon sorbent material that is "inject[ed]."[965] As explained by Downs-Boiler, the disclosed injected activated-carbon sorbent materials (e.g., sorbent injection systems using PAC) are part of *"downstream* pollution control systems such as . . . PAC injection systems."[966] Here, "downstream" is relative to the location of the combustion chamber, and thus after generation of the mercury-containing gas. The activated-carbon sorbent material is injected into a mercury-containing gas: "injection of a carbonaceous *sorbent* (e.g., powdered *activated carbon,* or PAC) *into the flue gas* upstream of the dust collector to *adsorb vapor-phase mercury.*"[967]

b. **Claim 25: Element 25(c)(2)—"Contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition"**

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[964] Ex. 1006 (Downs-Boiler) ¶ [0016] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019].
[965] Ex. 1006 (Downs-Boiler) ¶ [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0018].
[966] Ex. 1006 (Downs-Boiler) ¶ [0004]; see also Ex. 1007 (Downs-Boiler-Provisional)¶ [005].
[967] Ex. 1006 (Downs-Boiler) ¶¶ [0004], [0015], [0016], and [0025]; *see also* Ex. 1007 (Downs-Boiler-Provisional) in [005], [0018], [0019], and [0028].

649. In the context of conventional mercury removal by PAC injection, Downs-Boiler explains that adsorption (*i.e.,* contact) of the mercury by the sorbent occurring in the mercury-containing (flue) gas system (*i.e.,* downstream of the combustion chamber) has been successfully shown to form a mercury/sorbent composition:[968]

> injection of a carbonaceous *sorbent* (e.g., powdered *activated carbon,* or PAC) *into the flue gas* upstream of the dust collector to *adsorb vapor-phase mercury.* The *sorbent, and its burden of adsorbed mercury,* are subsequently removed from the flue gases in a downstream particulate collector. *Adsorption* is a technique that has often been successfully applied for the separation and removal of trace quantities of undesirable components.

The "sorbent, and its burden of adsorbed mercury" discloses a mercury/sorbent composition. For this process, described by Downs-Boiler as taking place in the dry emission control system such as an electrostatic precipitator or fabric filter, the "adsorption" of mercury refers to a process by which atoms, ions, or molecules in a fluid (typically a gas) are bound to the surface of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas," as per claim element 25(c).

650. Downs-Boiler recognizes that, when contacted with a sorbent, mercury in the mercury-containing gas forms a mercury/sorbent composition through the

[968] Ex. 1006 (Downs-Boiler) ¶ [0004]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [005]

sorbent "bond[ing] with adsorbed mercury species" and that the strength of this bond is improved by halogens.[969] In particular, Downs-Boiler explains that adding bromine in conjunction with activated carbon "results in an increased fraction of particulate-bound mercury," which includes an increase in the formation of sorbent-bound mercury.[970] This increase in the fraction of particulate-bound mercury is explained as leading to a mercury/sorbent composition due to the increased "reactivity of oxidized mercury with PAC."[971]

5. Claim 25: Element 25(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

651. Downs-Boiler discloses this claim element. Downs-Boiler explains that the desired removal of mercury from the flue gas is by a separation of the particulate-bound mercury. Separation of the particulate-bound mercury (mercury/sorbent composition), which includes the oxidized mercury adsorbed onto the PAC as discussed above regarding claim element 25(c)(2), is removed from the mercury-containing gas by a particulate collector as a way to clean the flue gas:[972]

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[969] Ex. 1006 (Downs-Boiler) 11 [0004]; Ex. 1007 (Downs-Boiler-Provisional) 44 [005].
[970] Ex. 1006 (Downs-Boiler) ¶ [0015]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018].
[971] Ex. 1006 (Downs-Boiler) ¶ [0016]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019].
[972] Ex. 1006 (Downs-Boiler) ¶ [0004]; see also Ex. 1007 (Downs-Boiler-Provisional) il [005].

> The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often been successfully applied for the separation and removal of trace quantities of undesirable components.

Downs-Boiler illustrates a number of example particulate collection devices that may be used to separate the mercury-sorbent composition to produce a cleaned gas, each of which were well known to a POSITA. These particulate collectors include "electrostatic precipitators (ESP) or fabric filters (FF), sometimes called baghouses" that "provide high-efficiency removal of particulate-bound mercury."[973]

B. CLAIMS DEPENDING FROM CLAIM 25

1. Claim 26: "The method of claim 25, wherein the coal comprises the added Br_2 HBr, the bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber."

652. Downs-Boiler discloses this claim. As I explain regarding claim element 25(b), Downs-Boiler describes that the bromine-containing reagent is added to the coal upstream of the combustion chamber. Exemplary bromine-containing reagents added to the coal "comprise, but [are] not limited to, alkali metal and alkaline

[973] Ex. 1006 (Downs-Boiler) ¶¶ [0003] [0023], Figures 4-6; *see also* Ex. 1007 (Downs-Boiler-Provisional) '111 [004] [0026], Figures 4-6.

earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)"[974] including "calcium bromide"[975] ($CaBr_2$).

2. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2 HBr, the bromide compound, or a combination thereof."

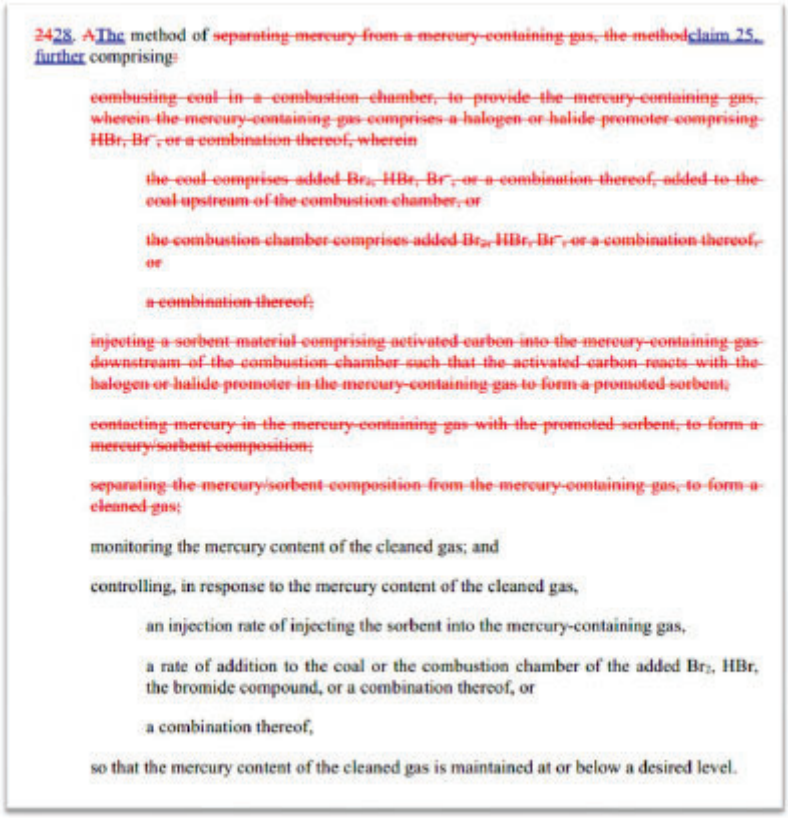
653. Downs-Boiler discloses this claim. As I explain regarding claim element 25(b), Downs-Boiler describes that the bromine-containing reagent is added to the combustion chamber (occasionally referred to as a "boiler combustion furnace" by Downs-Boiler). Exemplary bromine-containing reagents added to the combustion chamber "comprise, but [are] not limited to, alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)"[976] and "calcium bromide."[977]

3. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level."

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[974] Ex. 1006 (Downs-Boiler) ¶ [0021]; see also Ex. 1007 (Downs-Boiler-Provisional) IT [0024].
[975] Ex. 1006 (Downs-Boiler) ¶ [0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0022].
[976] Ex. 1006 (Downs-Boiler) ¶ [0019]; see also Ex. 1007 (Downs-Boiler-Provisional) IT [0022].
[977] Ex. 1006 (Downs-Boiler) ¶ [0015]; see also Ex. 1007 (Downs-Boiler-Provisional) 11 [0018].

654. Downs-Boiler discloses this limitation. As shown in the redlines below, Claim 28 copies its limitations from Claim 24:



2428. AThe method of separating mercury from a mercury-containing gas, the methodclaim 25, further comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or

a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level.

a. **Claim 28: Element 28(a)—"monitoring the mercury content of the cleaned gas; and"**

655. The language of claim element 28(a) is identical to the language of claim 1(e) [which is identical to claim element 24(e)]. Accordingly, the explanation I provide above for claim element 1(e) applies equally to claim element 28(a).

b. **Claim 28: Element 28(b)—"controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof"**

656. The language of claim element 28(b) is identical to the language of claim element 24(f)(1). Accordingly, the explanation I provide above for claim element 24(f)(1) applies equally to claim element 28(b).

c. **Claim 28: Element 28(c)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."**

657. The language of claim element 28(c) is identical to the language of claim element 1(f)(2) [which is identical to claim element 24(f)(2)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(f)(2).

4. Claim 29—"The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."

658. The language of claim 29 is substantially identical to the language of claim element 4. Accordingly, the explanation I provide above for claim 4 applies equally to claim 29.

5. Claim 30: "The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

659. Downs-Boiler discloses this claim. As described above for claim element 25(c), Downs-Boiler discloses that mercury in the flue gas is oxidized by the bromine-containing species and subsequently adsorbed onto activated carbon. Downs-Boiler describes that the use of the bromine-containing halogen in the presence of mercury results in an "increased fraction of mercury appearing in the

oxidized form"—the oxidized form being that of mercuric bromide ($HgBr_2$).[978] Downs-Boiler explains that the mercury forms a composition that comprises the element bromine, the sorbent material, and mercury owing to the "higher reactivity of oxidized mercury with PAC."[979] Thus, the composition includes mercury and the element bromine (in the form of $HgBr_2$), together adsorbed onto activated carbon.

C. INDEPENDENT CLAIM 23

660. As shown in the redline below, claim 23 is nearly identical to claim 25, with minor changes.

~~25~~23. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, or

a combination thereof~~.~~;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.

[978] Ex. 1006 (Downs-Boiler) 11 [0021]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0024].
[979] Ex. 1006 (Downs-Boiler) ¶ [0016]; *see also* Ex. 1007 (Downs-Boiler-Provisional)¶ [0019].

Accordingly, my analysis provided for claim 25 applies to claim 23.

1. Claim 23: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

661. The language of the preamble of claim 23 is identical to the preamble of claim 25. Accordingly, the explanation I provide above for the preamble of claim 25 applies equally to the preamble of claim 23.

2. Claim 23: Element 23(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas:"

662. The language of claim element 23(a) is identical to the language of claim element 25(a). Accordingly, the explanation I provide above for claim element 25(a) applies equally to claim element 23(a).

3. Claim 23: Element 23(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br^- or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof;"

663. The language of claim element 23(b) is similar to the language of claim element 25(b), and I refer to my discussion of that claim element. Claim 23(b) has the following changes, as compared to claim 25(b):

wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br-, or a combination thereof,

wherein the coal comprises added Br_2, HBr, Br-, ~~a bromide compound,~~ or a combination thereof, added to the coal upstream of the combustion chamber,

or the combustion chamber comprises added Br_2, HBr, Br-, ~~a bromide compound.~~ or a combination thereof.

or a combination thereof;

664. Claim element 23(b) is disclosed by Downs-Boiler. As explained with respect claim element 25(b), Downs-Boiler discloses that the combustion chamber and/or the coal upstream of the combustion chamber has added bromine-containing reagent. As further explained with respect to claim element 25(b) above, Downs-Boiler discloses that the bromine-containing reagent may comprise Br_2 and HBr. Additionally, Downs-Boiler discloses that the bromine-containing reagent may be an "aqueous solution of calcium bromide ($CaBr_2$)" which dissociates in solution with water to form bromide ions.[980] Downs-Boiler describes applying this "aqueous solution of calcium bromide" ($CaBr_2$) to the coa1[981] as well as directly into the combustion chamber.[982] Because these aqueous solutions (solutions of water) with calcium bromide ($CaBr_2$) dissociate to form bromide ions (Br^-), Downs-Boiler

[980] Ex. 1006 (Downs-Boiler) ¶¶ [0018]-[0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶¶ Till [0021] - [0022].
[981] Ex. 1006 (Downs-Boiler) ¶ [0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0022].
[982] Ex. 1006 (Downs-Boiler) ¶ [0018]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 'I [0021].

therefore discloses wherein the coal and/or combustion chamber comprises added Br_2, HBr, and/or Br^-.

665. Claim element 23(b) recites express examples of chemicals that qualify as halogen or halide promoters—"a halogen or halide promoter comprising HBr, Br^-, or a combination thereof"—and Downs-Boiler discloses these express examples. As described above for claim element 25(b), Downs-Boiler discloses adding "alkali metal and alkaline earth metal bromides, ***hydrogen bromide (HBr)*** or bromine (Br_2)" to the coal upstream of the combustion chamber and/or to the combustion chamber itself.[983] And, as described in the preceding paragraph, Downs-Boiler also discloses injecting bromide ions (Br^-) into the mercury containing gas of the combustion chamber in the form of an "aqueous solution of calcium bromide ($CaBr_2$)," which dissociates in solution with water to form the bromide ions.[984] Downs-Boiler explains that these bromine-containing species, including HBr and Br^- which are directly introduced into the mercury-containing gas (i.e., combustion gases) constitute a halogen or halide promoter.[985]

> ***Bromine species released during the combustion process enhance the oxidation of mercury as the combustion gases*** pass through the furnace 14 and, in particular, through the cooler

[983] Ex. 1006 (Downs-Boiler) ¶ [0021]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0024].
[984] Ex. 1006 (Downs-Boiler) ¶ [0018]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0021].
[985] Ex. 1006 (Downs-Boiler) ¶ [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0018].

sections of the boiler convection pass 18 and combustion air preheater 20.

666. As a result of the promotion by these HBr and Br^- halogens in the mercury containing gases, mercury capture by particulate collectors is improved and in particular, these halogen or halide promoters "enhance[] the removal of mercury across a PAC injection process."[986]

4. Claim 23: Element 23(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

667. The language of claim element 23(c) is identical to the language of claim element 25(c). Accordingly, the explanation I provide above for claim element 25(c) applies equally to claim element 23(c).

5. Claim 23: Element 23(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

668. The language of claim element 23(d) is identical to the language of claim element 25(d). Accordingly, the explanation I provide above for claim element 25(d) applies equally to claim element 23(d).

6. Claims Elements 23(c) and 25(c)

[986] Ex. 1006 (Downs-Boiler) ¶¶ [0015]-[0016]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 411 [0018]-[0019].

669. Several of the asserted claims have limitations in common, including:

- "a halogen or halide promoter comprising HBr, Br—, or a combination thereof" [claim elements 23(c)]
- "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition" [claim elements 23(c), claim 25(c)]

670. As described above, Downs-Boiler discloses that the mercury in the flue gas is adsorbed, and thus contacted, with the sorbent to form a mercury/sorbent composition. Downs-Boiler discloses that "PAC injection removes both oxidized and elemental mercury species."[987] Downs-Boiler further discloses that the injected sorbent adsorbs vapor-phase mercury and that subsequently, "the sorbent, and its burden of adsorbed mercury" are separated from the flue gas.[988] A POSITA would have understood that the "burden" of adsorbed mercury referred to by Downs-Boiler is the loading of mercury on the activated-carbon sorbent. Downs-Boiler additionally provides for the formation of a mercury/sorbent composition, referring to "the higher reactivity of oxidized mercury with PAC."[989] A POSITA would have understood that a chemical reaction is a form of contact and that the reaction between the oxidized mercury appearing as mercuric bromide ($HgBr_2$) with the sorbent results in the

[987] Ex. 1006 (Downs-Boiler) 11 [0004]; Ex. 1007 (Downs-Boiler-Provisional) 44 [005].
[988] Ex. 1006 (Downs-Boiler) ¶ [0004]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [005].
[989] Ex. 1006 (Downs-Boiler) ¶ [0016]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019].

formation of a mercury/sorbent composition. A POSITA would have further understood that "adsorbed" refers to the results of a process by which mercury atoms or ions in a fluid (e.g., a mercury-containing gas) adhere to the surface of a sorbent (e.g., activated carbon), and thus by definition the sorbent is "contacting mercury in a mercury-containing gas."

671. In addition, a person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition, because, for example, independent claim 25 of the '114 Patent recites a "mercury/sorbent composition" and its dependent claim 30 recites that "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."[990]

672. A POSITA would have also understood that the sorbent and halogen would have reacted to form at least a quantity of a mercury/sorbent composition upon contact.[991] Specifically, by 2003, it was well-known that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[992] HBr and Br^- are expressly disclosed by Element 23(b) as examples of a "halogen or halide promoter," and, as disclosed by Downs-Boiler, each are found in the mercury-containing gas, including

[990] Ex. 1001 ('114 Patent) at Claims 25, 30.
[991] *See* State of the Art, Sections XII.C.3, XII.G.2.
[992] Ex. 1062 (Crocker) at 2-3.

within the combustion gases of the boiler. A POSITA would have known that the introduction of halogens helped remove mercury by increasing the ability of the activated carbon to bind with the mercury. Further, through enhanced reactivity between mercury and activated carbon because of the halogens (bromine), a POSITA would have known that the sorbent/halogen complex would have been referred to as a "promoted" sorbent.

7. Claim 30: "wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury"

673. As described above, Downs-Boiler discloses that their process forms a mercury/sorbent composition. The cited portions of Downs-Boiler further confirm that this mercury/sorbent composition also includes bromine. The reaction that Downs-Boiler discloses as "due to the higher reactivity of oxidized mercury with PAC" occurs within the presence of each of the element bromine, the sorbent material, and mercury.[993] A POSITA would have understood that the reaction between the oxidized mercury appearing as mercuric bromide ($HgBr_2$) with the sorbent results in the formation of a composition with each of the element bromine, the sorbent material, and mercury. Downs-Boiler confirms that "PAC injection removes both oxidized and elemental mercury species, although removal efficiencies

[993] Ex. 1006 (Downs-Boiler) ¶ [0016]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019].

are higher for the oxidized form."[994] Because the reaction taking place between the oxidized mercuric bromide ($HgBr_2$) is explained by Downs-Boiler as adsorption by the sorbent, a POSITA would therefore have understood that each of the three constituents of the reaction are present in the resultant mercury/sorbent composition which comprises the element bromine, the sorbent material, and mercury.

D. INDEPENDENT CLAIM 1

674. As shown in the redline below, claim 1 is nearly identical to claim 23, with additions shown below.

~~23~~1. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; ~~and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.

[994] Ex. 1006 (Downs-Boiler) ¶ [0004]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [005].

Accordingly, my analysis provided for claim 23 applies to claim 1.

1. Claim 1: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

675. The language of the preamble of claim 1 is identical to the preamble of claim 23 [which is identical to the preamble of claim 25]. Accordingly, the explanation I provide above for the preambles of claims 23 and 25 applies equally to the preamble of claim 1.

2. Claim 1: Element (1)(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas,"

676. The language of claim element 1(a) is identical to the language of claim element 23(a) [which is identical to claim element 25(a)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(a).

3. Claim 1: Element (1)(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br, or a combination thereof, or a combination thereof:"

677. The language of claim element 1(b) is identical to the language of claim element 23(b) [which is similar to claim element 25(b)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(b).

4. Claim 1: Element (1)(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition:"

678. The language of claim element 1(c) is identical to the language of claim element 23(c) [which is identical to claim element 25(c)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(c).

5. Claim 1: Element (1)(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

679. The language of claim element 1(d) is identical to the language of claim element 23(d) [which is identical to the language of claim element 25(d)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(d).

6. Claim 1: Element (1)(e)—"monitoring the mercury content of the cleaned gas; and"

680. This limitation is disclosed by Downs-Boiler. The mercury content is monitored, as depicted by the Y-axis of Figure 3 *(i.e.,* the "Hg concentration" in µg/dscm).[995] The units "µg/dscm" refer to micrograms of mercury per standard cubic meter of flue gas on a dry basis.

[995] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

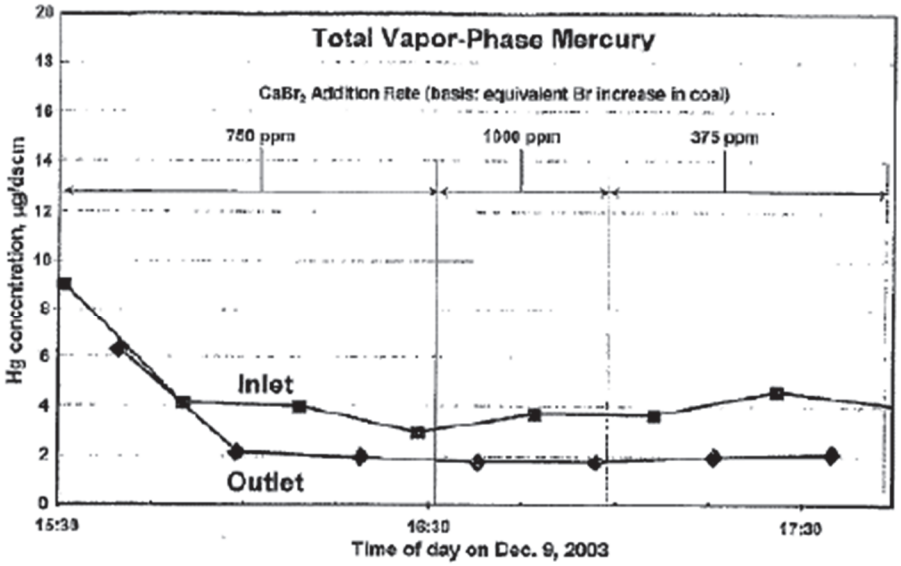


FIG. 3

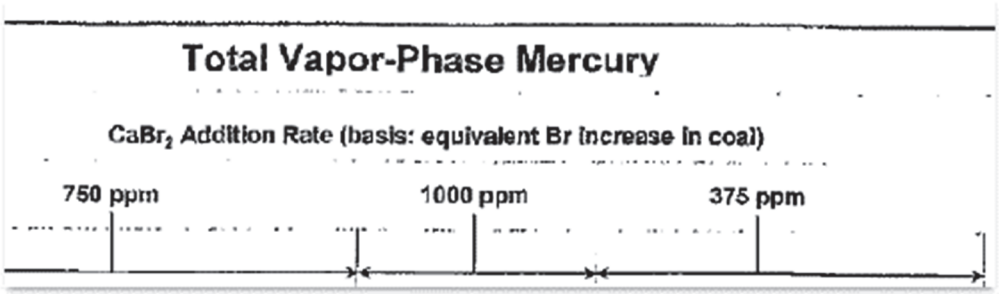
In particular, Figure 3 shows that the mercury content of the cleaned gas (the data set provided by diamond markers for the outlet of the particulate collector) is monitored for a period of over two hours.[996]

7. Claim 1: Element (1)(f)(1)—"controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof,"

681. This limitation is obvious over Downs-Boiler. As illustrated by Figure 3 of Downs-Boiler, excerpted below, in response to continuously monitoring the mercury content of the cleaned gas, the injection rate of the promoter (in this case

[996] Ex. 1006 (Downs-Boiler) Figure 3; *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

$CaBr_2$) was continuously adjusted between a range of 375 to 1000 parts per million of a bromine-containing reagent ($CaBr_2$).[997]



By adjusting the amount of bromine-containing reagent applied, it would have been understood by a POSITA that this would control the sorbent composition in the flue gas (e.g., the amount of bromine and/or the amount of mercury adsorbed on the sorbent). A POSITA reviewing the monitored data as presented by Figure 3 of Downs-Boiler would have understood that the monitored mercury content at the outlet of the particulate collector could be used to control the addition rate of the bromine-containing reagent thereby controlling the sorbent composition of injected PAC in response to the monitored mercury content of the cleaned gas.

682. It would have also been obvious to control the sorbent injection rate. As described above, Downs-Boiler discloses that the injection of sorbents was effective for the removal of mercury but as the rate of injecting the sorbent into the mercury-containing gas increases, the "economics of high injection rates can be prohibitive"

[997] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

due to the costs of the consumable sorbent material.[998] The normal desire of a POSITA to improve on a given process would have been to adjust the result-effective variable of the injection rate of the sorbent so as not to wastefully inject excessive sorbent once sufficient mercury removal was demonstrated, in order to minimize costs associated with operating the sorbent injection system. Furthermore, due to the variability of the composition of coal as a fuel source (including for example, native mercury and halogen content), as described in the State of the Art,[999] it would have been obvious that some amount of adjustment to the rate of injection of the sorbent into the flue gas would be performed as part of routine process control and optimization to account for variances in the coal.

8. Claim 1: Element (1)(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

683. As I discuss in the State of the Art, the EPA and other regulatory bodies proposed rules that, upon implementation, would have required mercury emissions reductions by 70%. Indeed, Downs-Boiler specifically calls out the role of the EPA in setting standards for regulating mercury emissions from coal fired utility boilers.[1000] A POSITA would have expected a cleaned gas to be a gas stream that

[998] Ex. 1006 (Downs-Boiler) ¶ [0004]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [005].
[999] State of the Art, § XII.B.1.
[1000] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [002].

was in compliance with the emissions standards proposed and promulgated by the EPA for the coal-fired utility industry. Accordingly, a POSITA would have understood that the mercury content of the cleaned gas should be controlled using the process disclosed by Downs-Boiler such that the mercury emissions of a particular coal-fired plant are at or below a desired level as determined by the standards promulgated by the EPA. Even without the particular target and the motivation provided by the EPA, it would have been obvious to a POSITA to meet and then maintain a particular mercury removal goal by endeavoring to stay within a threshold value of the desired level.

E. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

684. This limitation is disclosed by Downs-Boiler. According to Figure 3, reproduced below as annotated, Downs-Boiler indicates that the disclosed method for removing mercury from the flue gas resulted in mercury emissions at the outlet of the fabric filter of approximately 2 μg/dscm (blue) as compared to an initial value *(i.e.,* the mercury inventory of the system) at the inlet of the fabric filter of approximately 9 μg/dscm (red).[1001]

[1001] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

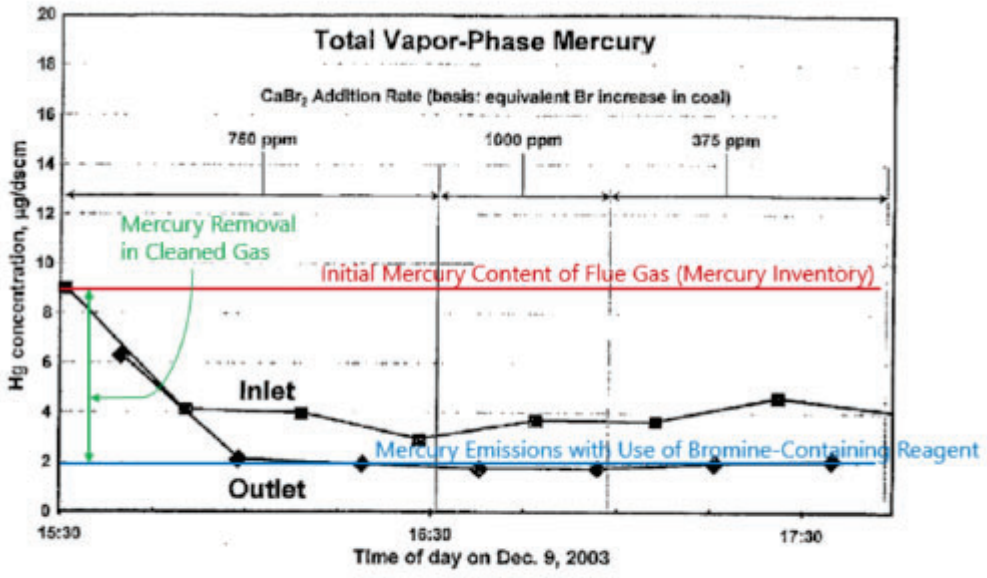


FIG. 3

Therefore, the use of the method disclosed by Downs-Boiler in conjunction with a fabric filter resulted in a system mercury removal of approximately 7 µg/dscm (green). This removal of the mercury in the mercury containing gas (7 µ g/dscm) as compared to the mercury inventory of the system (9 µg/dscm) may also be expressed as a percentage: at least 77 wt% of the mercury in the mercury-containing gas was removed—or in other words: removing greater than 70 wt% of the mercury in the mercury-containing gas.

685. Furthermore, as described in the State of the Art,[1002] a POSITA would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations requiring 70% mercury removal, including the EPA's Clean Air

[1002] State of the Art, XII.D — XII.F.

Mercury Rule (CAMR). Downs-Boiler further teaches compliance with EPA standards regulating mercury emissions from coal-fired plants.[1003] Notice of these regulations exerted a strong outside impetus on the industry to adjust processes to comply with the regulations' eventual implementation. Through routine process optimization and routine experimentation, a POSITA would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

2. Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."

686. This limitation is obvious in view of Downs-Boiler. As described above regarding Claim 2, Downs-Boiler discloses removing greater than 77 wt% of the mercury in the flue gas. In addition to the reasons for Claim 2, a POSITA would understand that that the mercury removal on the sorbent alone would meet or exceed 70%. Downs-Boiler discloses that only "25% of the coal-fired power plants in the U.S. are equipped with wet FGD systems" (scrubbers), and discloses "PAC injection systems" (activated carbon) as an alternative to "downstream pollution control

[1003] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [002].

systems such as wet [scrubbers] 22 and SDA 24 FGD systems."[1004] This impact would be particularly pronounced for coal-fired utility plants using lignites or blends of high volatility coals that would produce minimal unburned carbon (*e.g.,* loss on ignition) particulate in the flue gas stream,[1005] resulting in a higher proportion of the mercury in the mercury-containing gas to bind to the sorbent.

687. Downs-Boiler notes that "the presence of unburned carbon" is a factor that has "been shown to affect the conversion of elemental mercury to oxidized mercury species" and this unburned carbon *(i.e.,* LOI) would scavenge mercury from the flue gas, thereby affecting the percentage of mercury on the sorbent.[1006] Specifically, Downs-Boiler discloses that power stations burning western lignite coals, which produce a lower "percentage of oxidized mercury" and "have low chloride content" would benefit from the disclosed Hg control methods.[1007] Such plants typically exhibit very low levels of LOI in addition to suffering from very low concentrations of inherent chlorine in their flue gas. Under such circumstances, Hg capture on inherent unburned carbon would have been minimal in plants using western lignite coals and would therefore not have a significant effect on the

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1004 Ex. 1006 (Downs-Boiler), ¶¶ [0007, 0015]; Ex. 1007 (Downs-Boiler-Provisional) ¶¶ [009, 0018].

1005 *See* State of the Art, § XII.B.1.

1006 Ex. 1006 (Downs-Boiler) ¶ [0005]; Ex. 1007 (Downs-Boiler-Provisional) 4111 [006].

1007 Ex. 1006 (Downs-Boiler) ¶ [0005]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [006].

percentage of mercury on the sorbent. Consequently, adding bromine-containing species to the furnace of coal-fired utility plants burning lignite and related coals, and that are not configured with a scrubber or a spray dryer absorber while injecting a sorbent ahead of the particle collection device, as Downs-Boiler teaches, ensures that virtually all the Hg captured in a particle collection device would be bound to the sorbent. Furthermore, Downs-Boiler also teaches how to adjust the bromine addition level to achieve highly efficient Hg removal, including greater than 70% removal.

688. Additionally, a POSITA would have understood that that the mercury removal on the sorbent alone would meet or exceed 70%. Downs-Boiler discloses that only "25% of the coal-fired power plants in the U.S. are equipped with wet FGD systems" (scrubbers), and discloses "PAC injection systems" (activated carbon) as an alternative to "downstream pollution control systems such as wet 22 and SDA 24 FGD systems."[1008] Downs-Boiler also discloses a plant that burns "lignite coals," which produces a lower "percentage of oxidized mercury" on account of "low chloride content."[1009] A POSITA would have understood that plants burning lignite, without a scrubber or spray-dryer adsorber, as taught by Downs-Boiler adding

[1008] Ex. 1006 (Downs-Boiler) 111 [0007, 0015, 0025]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶¶ [009, 0018, 0028].

[1009] Ex. 1006 (Downs-Boiler) ¶¶ [0005, 0020]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶¶ [006, 0023].

bromine in conjunction with activated carbon, the activated carbon would be the component that accounts for almost all of the mercury removal.

3. Claim 4: "The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 2 of the sorbent material."

689. This claim would have been obvious over Downs-Boiler. Claim 4 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and has the dual-benefit of oxidizing mercury and promoting activated carbons) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would have led to an unexpected result from what was already known to one of skill in the art.

690. As described in the State of the Art,[1010] it was known that the saturation limit of activated carbon for bromine (i.e., how much bromine the activated carbon can actually adsorb at equilibrium), was up to 31 to 38 grams per 100 grams of activated carbon. Given the residence times in flue gas, and other inefficiencies, a person of ordinary skill in the art would have understood that the actual bromine loaded onto activated carbon would have been less than the saturation limit.

[1010] State of the Art, § XII.C.3.

691. A POSITA would have recognized that there would be sufficient bromine in the flue gas, according to the processes disclosed by Downs-Boiler, to provide a ratio of between 1 g to 30 g of bromine per 100 g of activated carbon. A POSITA would have been motivated to use near the bromine-saturation limit of the activated carbon because, in addition to the enhanced removal of mercury on sorbent with the use of halogens as disclosed by Downs-Boiler,[1011] it was known in the art that mercury oxidized by a halide, as "in the form of mercuric chloride, is soluble in water, making it amenable to removal in sulfur dioxide scrubbers," as discussed by Downs-Boiler.[1012] The fact that halides both contribute to the solubility of mercury in water rendering it trivial to remove in a scrubber and also enhance reactivity between mercury and activated carbons is confirmed as well-known in the art, which indicates that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[1013]

692. Through natural process optimization and routine experimentation, a POSITA would have adjusted the rate of addition of bromine-containing species

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[1011] Ex. 1006 (Downs-Boiler) TT [0016], [0006]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶¶ [0019], [007].

[1012] Ex. 1006 (Downs-Boiler) ¶ [0003]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [004].

[1013] Ex. 1062 (Crocker) at 2-3.

and/or activated carbon injection rate to achieve halide promoter on the activated-carbon sorbent from about 1 g to about 30 g.

4. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

693. This limitation is disclosed by Downs-Boiler for the reasons discussed in Ground E for Claim Element 25(b), Claim 27, and Claim 23. As described above with respect to Claim 1, Downs-Boiler discloses a halogen or halide promoter *(i.e.,* a bromine-containing reagent).[1014] Downs-Boiler further discloses that the bromine-containing reagent may comprise "hydrogen bromide" (HBr).[1015] Downs-Boiler discloses adding "bromine" (Br_2), "hydrogen bromide" (HBr) and aqueous "calcium bromide" to the combustion chamber. According to Downs-Boiler, the bromine promoters may be "fed to the boiler combustion zone 14."[1016] HBr and Br^- (e.g., from the dissociated calcium bromide) are expressly disclosed by Claims 1 and 23 of the '114 Patent as examples of "a halogen or halide promoter." Indeed, Downs-Boiler indicates that such an embodiment where the combustion chamber comprises the halogen or halide promoter was successfully tested by injecting a solution of the

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[1014] Ex. 1006 (Downs-Boiler) 11 [0015]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0018]

[1015] Ex. 1006 (Downs-Boiler) ¶ [0021]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0024].

[1016] Ex. 1006 (Downs-Boiler) ¶ [0022]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0025].

promoter *"into the combustion chamber 14* through a coal burner."[1017] Accordingly, Downs-Boiler discloses that the halogen in the combustion chamber acts as a promoter (*e.g.,* "enhances mercury removal").[1018]

5. Claim 6: "The method of claim 1, wherein the coal comprises added Br_2 HBr. Br or a combination thereof added to the coal upstream of the combustion chamber."

694. The language of claim 6 is similar to the language of Claim Element 25(b) and Claim 26, and I refer to my discussion in Ground E. Claim 6 has the following changes, as compared to claim 26:

> wherein the coal comprises ~~the~~ added Br_2, HBr, Br-, ~~the bromide compound~~ or a combination thereof, added to the coal upstream of the combustion chamber

695. Claim 6 is disclosed because, as discussed for claim 26 in Ground E, Downs-Boiler discloses a bromine-containing reagent that may comprise "hydrogen bromide (HBr) or bromine (Br_2)".[1019] This bromine-containing reagent is applied to the coal upstream of the combustion chamber.

6. Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."

[1017] Ex. 1006 (Downs-Boiler) ¶ [0018] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0021].

[1018] Ex. 1006 (Downs-Boiler) ¶ [0015]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0018].

[1019] Ex. 1006 (Downs-Boiler) 11 [0021]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0024].

696. This limitation is obvious in view of Downs-Boiler. Downs-Boiler explicitly discloses that the promoter (*i.e.,* the bromine-containing reagent) "may be fed to the boiler combustion zone 14 in ***gaseous, liquid,* or *solid form.***"[1020] Downs-Boiler also explicitly discloses that the promoter may be in the form of an "***aqueous solution.***"[1021] A POSITA, would have known the range of temperatures and injection points for the conventional PAC injection system disclosed by Downs-Boiler and would have known that within the relatively high temperature flue gas the bromine-containing promoter would be in a gaseous form. A POSITA would have understood that when subjected to the range of temperatures of the combustion and flue gas cleaning system, that the promoter would not have condense into a liquid and would have remained in gaseous form.

7. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

697. This limitation is disclosed by Downs-Boiler. As discussed above for claim element 1(c), Downs-Boiler discloses the use of a "sorbent injection system" for the purpose of injecting a "carbonaceous sorbent" including at least "powdered

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[1020] Ex. 1006 (Downs-Boiler) ¶ [0022] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0025].

[1021] Ex. 1006 (Downs-Boiler) ¶ [0019] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0022].

activated carbon (PAC), carbons and chars produced from coal and other organic materials, and unburned carbon produced by the combustion process itself."[1022]

8. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

698. Downs-Boiler discloses this limitation. Downs-Boiler discloses a combustion chamber (i.e. a "combustion furnace 14") that comprises a "boiler 12."[1023] Furthermore, in Figures 2 and 4-6 Downs-Boiler illustrates a combustion chamber 14 (red) comprising a boiler 12 (green), as indicated by representative Figure 5 reproduced below as annotated:[1024]

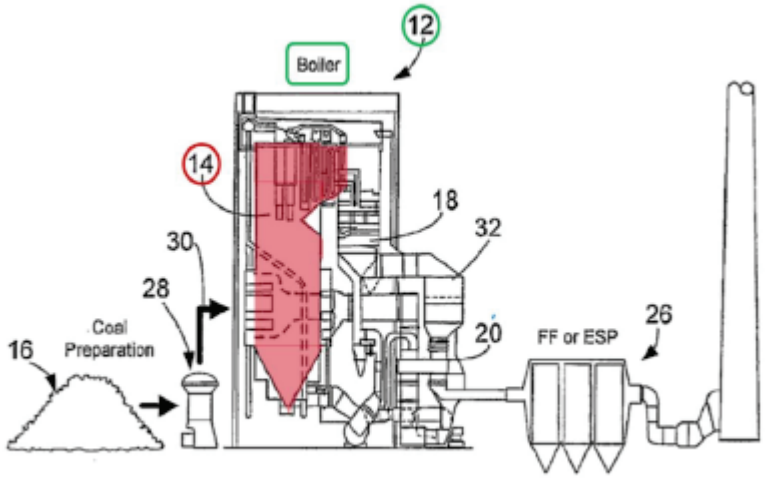


FIG. 5

9. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

[1022] Ex. 1006 (Downs-Boiler) ¶ [0025] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0028].

[1023] Ex. 1006 (Downs-Boiler) 11 [0015]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0018].

[1024] Ex. 1006 (Downs-Boiler) Figures 2, 4-6; *see also* Ex. 1007 (Downs-Boiler-Provisional) Figures 2, 4-6.

699. Downs-Boiler discloses this limitation. Downs-Boiler specifically describes various forms of mercury as being present within a flue gas:[1025]

> Mercury appears in coal combustion flue gases in both solid and gas phases (particulate-bound mercury and vapor-phase mercury, respectively). The so called particulate-bound mercury is really vapor-phase mercury adsorbed onto the surface of ash or carbon particles. Due to the high volatility of mercury and many of its compounds, most of the mercury found in flue gases is vapor-phase mercury. Vapor-phase mercury can appear as elemental mercury (elemental, metallic mercury vapor) or as oxidized mercury (vapor-phase species of various compounds of mercury).

The invention taught by Downs-Boiler promises an effective low-cost solution for "mercury removal" from the flue gases "at coal-fired electric plants."[1026] The preamble of claim 1 of Downs-Boiler also identifies "a flue gas" as being such a mercury-containing gas from which to remove mercury.[1027]

10. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

700. Downs-Boiler discloses this limitation. As illustrated by Figures 4-6 of Downs-Boiler, representative Figure 6 reproduced below as annotated, Downs-Boiler describes a coal-fired electric utility plant that can have a number of downstream

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[1025] Ex. 1006 (Downs-Boiler) ¶ [0002]; *see also* Ex. 1007 (Downs-Boiler-Provisional) III [003].

[1026] Ex. 1006 (Downs-Boiler) 11 [0016]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0019].

[1027] Ex. 1006 (Downs-Boiler) Claim 1; *see also* Ex. 1007 (Downs-Boiler-Provisional) Claim 1.

pollution control devices including particulate collection systems (*e.g.,* a fabric filter (FF) system and/or an electrostatic precipitator (ESP) system) (purple) and a scrubber (*e.g.,* wet flue gas desulfurization (FGD) system) (yellow).[1028]

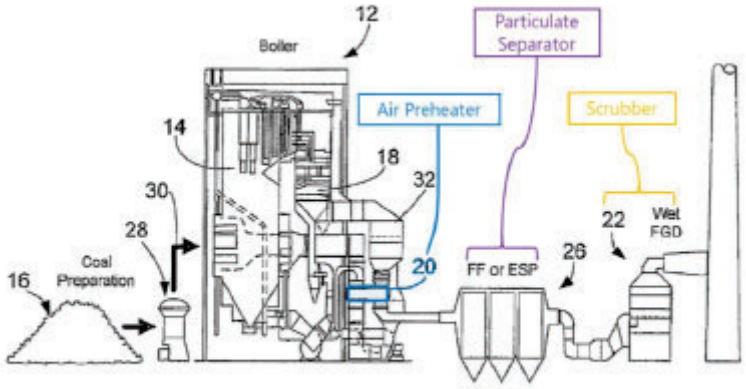


FIG. 6

The use of the bromine-containing reagent as disclosed by Downs-Boiler "thereby enhance[es] the overall removal of mercury in ***downstream pollution control devices***."[1029] Specifically, Downs-Boiler explains that a particular advantage of the disclosed invention is that it "enhances removal of mercury across ***particulate collectors 26*** such as fabric filters (FF) and electrostatic precipitators (ESP)."[1030] As further explained by Downs-Boiler, the upstream injection of a sorbent means that

[1028] Ex. 1006 (Downs-Boiler) Figure 6 (annotated; *see also* Ex. 1006 (Downs-Boiler) Figures 4-5; Ex. 1007 (Downs-Boiler-Provisional) Figures 4-6.

[1029] Ex. 1006 (Downs-Boiler) 11 [0007] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [009].

[1030] Ex. 1006 (Downs-Boiler) ¶ [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0018].

the "sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases ***in a downstream particulate collector***."[1031]

701. The concept of using a particulate separator or a scrubber in conjunction with sorbent injection is further confirmed by the EPA, explaining that for "direct sorbent injection, after sorbent is introduced into the flue gas, it adsorbs Hg and other contaminants and is ***captured downstream*** in an existing or sorbent-specific [(particulate matter)] control device."[1032] Therefore, to the extent Downs-Boiler fails to explicitly disclose injection of the sorbent material into the mercury-containing gas occurring upstream of a particulate separator or a scrubber this would have been obvious to a POSITA at the time.

11. Claim 20: "The method of claim 1, wherein the combustion chamber comprises added Br_2 HBrg Br^- or a combination thereof."

702. Downs-Boiler discloses this limitation. The language of claim 20 is similar to the language of Claim 27, and I refer to my discussion of that claim. Claim 20 has the following changes, as compared to claim 27:

> wherein the combustion chamber comprises ~~the~~ added Br_2, HBr, Br-, ~~the bromide compound~~, or a combination thereof."

1031 Ex. 1006 (Downs-Boiler) ¶ [0004] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [005].

1032 Ex. 1009 (EPA-Proposal) at 4676 (emphasis added).

As previously described, Downs-Boiler explains that the bromine-containing reagent may comprise an "alkali metal and alkaline earth metal bromides, ***hydrogen bromide (HBr)*** **or** ***bromine (Br_2)***."[1033] As also described above regarding claim element 23(b) and claim element 1(b), Downs-Boiler further explains introducing an "aqueous solution of calcium bromide ($CaBr_2$)" to the combustion chamber that A POSITA would have understood that the $CaBr_2$ would have dissociated in water to form bromide (Br) ions, which upon introduction into the combustion chamber, would have been present in the mercury-containing gas.[1034]

F. INDEPENDENT CLAIM 24

703. Claim 24 combines limitations of Claims 1, 23 and 25. For the same reasons, Downs-Boiler also renders obvious Claim 24

1. Claim 24: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

704. The language of the preamble of Claim 24 is identical to the preamble of claim 23 [which is identical to the preamble of claim 25].

[1033] Ex. 1006 (Downs-Boiler) ¶ [0021] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0024].

[1034] Ex. 1006 (Downs-Boiler) ¶ [0018]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0021].

~~1~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the ~~monitored~~ mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the ~~sorbent composition~~coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or

a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level.

Accordingly, the explanation I provide above for the preambles of claims 25 and 23 applies equally to the preamble of claim 24.

2. Claim 24: Element 24(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas:"

705. The language of claim element 24(a) is identical to the language of claim element 23(a) [which is identical to claim element 25(a)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 24(a).

3. Claim 24: Element 24(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br^-, or a combination

thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof."

706. The language of claim element 24(b) is identical to the language of claim element 23(b). Accordingly, the explanation I provide above for claim element 23(b) applies equally to claim element 24(b).

4. Claim 24: Element 24(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition:"

707. The language of claim element 24(c) is similar to the language of claim element 23(c) [which is identical to the language of claim element 25(c)], and I refer to my discussion of those claim elements. Claim element 24(c) has the following changes:

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide

promoter in the mercury-containing gas to form a promoted sorbent;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition; ~~and~~"

As described above with respect to claim 30, Downs-Boiler describes that a mercury/sorbent/bromine composition is formed (which thus includes a

mercury/sorbent composition), in that the oxidized mercury ($HgBr_2$) is adsorbed onto the PAC sorbent.

708. In addition to contacting (adsorbing) one another, a POSITA would have understood that the activated-carbon sorbent and halogen (bromine) would have reacted to form at least a quantity of promoted sorbent. For example, it was well known that halides improved mercury capture both by: oxidizing elemental mercury (Hg^0) to the more easily removed Hg^{2+} form, and by enhancing the reactivity of Hg^0 with activated carbons. A POSITA would have also known that on account of the enhanced reactivity of activated carbon to mercury, the sorbent/halogen composition would have been considered a "promoted" sorbent. A POSITA would have also understood that the sorbent and halogen would have reacted to form at least a quantity of promoted sorbent upon contact.[1035] Specifically, by 2003, it was well-known that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[1036] A POSITA would have known that the introduction of halogens helped remove mercury by increasing the ability of the activated carbon to bind with the mercury. Thus, a POSITA would have known that the sorbent/halogen complex would have been referred to as a "promoted" sorbent. This is also confirmed by

1035 *See* State of the Art, Sections XII.C.3, XII.G.2.

1036 Ex. 1062 (Crocker) at 2-3.

Downs-Boiler which admits that it was known in the art that halogens may be "incorporated into the carbonaceous sorbent" to "yield sorbents that more strongly bond with adsorbed mercury species" (i.e., forming a promoted sorbent).[1037]

5. Claim 24: Element 24(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

709. The language of claim element 24(d) is identical to the language of claim element 23(d) [which is identical to the language of claim element 25(d)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 24(d).

6. Claim 24: Element 24(e)—"monitoring the mercury content of the cleaned gas; and"

710. The language of claim element 24(e) is identical to the language of claim element 1(e). Accordingly, the explanation I provide above for claim element 1(e) applies equally to claim element 24(e).

7. Claim 24: Element 24(f)(1)—"controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2 HBr, the bromide compound, or a combination thereof, or a combination thereof,"

[1037] Ex. 1006 (Downs-Boiler) ¶ [0004]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [005].

711. The language of this claim element 24(f)(1) is similar to the language of claim element 1(f)(1), and a I refer to my discussion of claim element 1(f)(1) above. Claim 24(f)(1) has the following changes, as compared to claim 1(f)(1):

> controlling, in response to the mercury content of the cleaned gas,
>
> ~~the sorbent composition.~~
>
> an injection rate of injecting the sorbent into the mercury-containing gas,
>
> a rate of addition to the coal or the combustion chamber of the added Br2, HBr, the bromide compound, or a combination thereof,
>
> or a combination thereof

In addition to controlling an injection rate of the sorbent into the mercury-containing gas as described above with respect to claim element 1(f)(1), controlling a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, or the bromide compound is obvious over Downs-Boiler. Figure 3 of Downs-Boiler, reproduced below as annotated, illustrates measuring mercury content of the cleaned gas (Y-Axis) and controls the injection rate of the bromide compound ($CaBr_2$) of up to 1000 ppm:[1038]

[1038] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

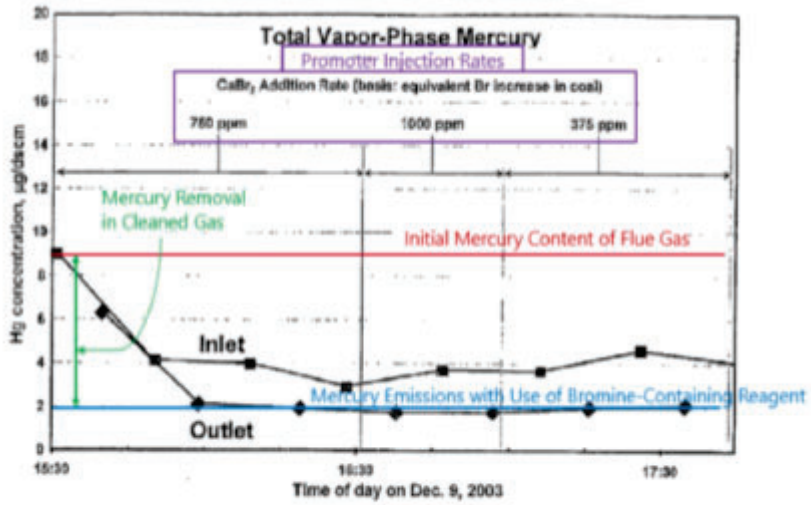


FIG. 3

The associated description of Figure 3 of Downs-Boiler discloses controlling the rate of addition to the coal or the combustion chamber of the added Br_2, HBr, and/or the bromide compound (*e.g.,* "aqueous solution of calcium bromide ($CaBr_2$) [] injected into the combustion chamber") (purple) was controlled at rates of addition up to 1000 parts per million of a bromine-containing reagent ($CaBr_2$).[1039]

712. As indicated in Figure 3, reproduced as annotated above, Downs-Boiler illustrates continuously monitoring the mercury content of the gas in response to the rate of addition to the coal or the combustion chamber of the added bromine-containing reagent, as part of a parametric test to characterize the performance of the bromine-containing reagent for the removal of mercury. To the extent Downs-Boiler

[1039] Ex. 1006 (Downs-Boiler) ¶ [0018], Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0021], Figure 3.

does not explicitly disclose the controlling of the rate of addition of the bromine *in response to the mercury content* of the cleaned gas, this is obvious over Downs-Boiler. A POSITA reviewing the monitored data of the parametric test as presented by Figure 3 of Downs-Boiler would have understood that the monitored mercury content at the outlet of the fabric filter is the information that could be used to continuously adjust a rate of addition of the bromine-containing reagent (*e.g.,* one of the four rates provided: 0, 375, 750, and 1000 ppm) by selecting a given rate or by interpolating an intermediate value in response to the monitored mercury content of the cleaned gas.

8. Claim 24: Element 24(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

713. The language of claim element 24(f)(2) is identical to the language of claim element l(f)(2). Accordingly, the explanation I provide above for claim element l(f)(2) applies equally to claim element 24(f)(1).

XXII. GROUND D: OBVIOUSNESS OF THE '114 PATENT OVER DOWNS-BOILER IN VIEW OF EPA-PROPOSAL

714. It is my opinion that Downs-Boiler in view of the EPA-Proposal renders obvious each of the asserted claims of the '114 patent. Elements and claims not mentioned below are disclosed and/or obvious for the reasons stated above in Ground C above.

A. REASONS TO COMBINE

715. A POSITA would have looked to the EPA-Proposal to identify a target for needed mercury removal of 70% or more of mercury from the mercury-containing flue gas. Downs-Boiler discusses EPA standards regulating mercury emissions from coal-fired plants.[1040] The EPA-Proposal discusses several ways to reduce mercury emissions to a desired level, including by injecting activated-carbon sorbent material (bare or impregnated with halides), and controlling the sorbent injection rate to achieve the desired level of mercury removal.

716. As I describe in the State of the Art section,[1041] a person of skill in the art would have been motivated at least by January 2004 to operate their power plants in a manner compliant with the EPA proposed rules in order to avoid eventual regulatory fines that would be imposed for violating those limits, and would have been motivated to try remediation methods described by the EPA. On December 15, 2003, the EPA signed proposed rules and published them on January 30, 2004 in the Federal Register.[1042] The EPA further explained that the "rules would significantly reduce emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury from power plants," and explained that publication "in the Federal Register marks the

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1040 Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) irj [002].

1041 State of the Art, § § XII.D — XII.F.

1042 Ex. 1009 (EPA-Proposal) at 4652 (Cover).

beginning of a 60 day comment period" that included public hearings.[1043] The proposed rules stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018."[1044] The EPA again announced this "70 percent" reduction on February 24, 2004, in mercury emissions when it further sought public comment.[1045] Accordingly, as of January 2004, if not earlier, the EPA put the power-generation industry on notice that upcoming regulations would require a 70% reduction in mercury emissions, and plant operators were motivated to identify processes that would achieve those limits.

717. A POSITA would have had a reasonable expectation of success in combining Downs-Boiler with the EPA-Proposal because both references address injection of activated carbon for purposes of removing mercury from a flue gas. As discussed above in Ground C, Downs-Boiler discloses injecting an activated carbon into the mercury-containing flue gas, such as upstream of a particulate collector. Likewise, the EPA-Proposal describes "sorbent injection" to introduce sorbent into the flue gas. "Sorbents can be introduced by two basic methods: by channeling flue gas through a bed of sorbent or by direct sorbent injection."[1046] With sorbent injection, "after sorbent is introduced into the flue gas, it adsorbs Hg and other

1043 Ex. 1057 (1/29/2004 EPA Press Release).
1044 Ex. 1009 (EPA-Proposal) at 4698.
1045 Ex. 1058 (2/24/2004 EPA Press Release).
1046 Ex. 1009 (EPA-Proposal) at 4676.

contaminants and is captured downstream in an existing or sorbent-specific PM [(particulate matter)] control device."[1047] The EPA specifically mentions "activated carbon" as an example of a sorbent that can be injected into a flue gas.[1048]

B. DISCLOSURE OF DOWNS-BOILER IN VIEW OF EPA-PROPOSAL

1. Claims 1, 24, and 28:

718. From the disclosure of Downs-Boiler, POSITA would have found claims 1, 24, and 28 (and claims depending from them) obvious in view of EPA-Proposal in order to achieve mercury emissions targets.

a. **"controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof" [Claim Element 1(f)(1)]**

b. **"controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof" [Claim Elements 24(f)(1), 28(b)]**

719. As described above in Ground C, Downs-Boiler monitors mercury content and controls injection rate of bromine and/or a bromide compound. The EPA-Proposal discusses an additional control variable that can be used to adjust mercury content in the mercury-containing gas. Regarding claim element l(f)(1), it

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1047 *Id.*

1048 727 Ex. 1009 (EPA-Proposal) at 4676.

would have been obvious for a POSITA to also continuously adjust the injection rate of the sorbent into the mercury-containing gas in order to achieve the desired mercury emissions targets (discussed in the subsection above). As discussed by the EPA, when using sorbents such as activated carbon, the "extent of potential Hg removal is dependent on: (1) Efficient distribution of the sorbent (e.g., activated carbon) in the flue gas; (2) *the amount of sorbent needed* to achieve a specific level of Hg removal which will vary depending on the fuel being burned."[1049] Accordingly, in operating a dry-emission control system, such as the electrostatic precipitator and/or fabric filter as in Downs-Boiler, a POSITA would have been motivated to continuously adjust an injection rate of the sorbent into the mercury-containing gas, in response to the continuous monitoring of the mercury level, to provide the desired amount of sorbent needed to remove mercury.

c. **"…so that the mercury content of the cleaned gas is maintained at or below a desired level" [Claim Elements 1(f)(2), 24(f)(2), 28(c)]**

720. As discussed in Ground C, Downs-Boiler illustrates measuring the mercury content as a response of controlling the rate of addition of bromine-containing components in a parametric test of the performance of the bromine-containing reagent. A POSITA would have understood that this enables controlling, in response to the mercury content of a cleaned gas an application rate of the added

[1049] Ex. 1009 (EPA-Proposal) at 4676 (emphasis added).

bromine and/or an injection rate of the sorbent and/or to maintain the mercury content of the cleaned gas at or below a desired level.

721. Downs-Boiler acknowledges the existing needs in the coal-fired utility industry in meeting the advancing EPA standards.[1050] Downs-Boiler suggests that the disclosed invention would help towards meeting the needs in the industry for new methods and processes to meet the announced EPA regulations.[1051] The EPA-Proposal stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018."[1052] As part of enforcing this rule, the EPA-Proposal contemplated a "system of automatic penalties" including "financial penalties" based on mercury emissions exceeding the target limit.[1053] A POSITA would have been motivated to target at least this 70% emissions reduction as a "desired level." A POSITA would therefore have been strongly motivated to adjust process parameters (such as the bromine addition rate, as disclosed by Downs-Boiler), in order to achieve a desired level of mercury content in the flue gas in compliance with the 70% emissions reduction target.

2. <u>Claims 2 and 3:</u>

[1050] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [002].

[1051] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [002].

[1052] Ex. 1009 (EPA-Proposal) at 4698.

[1053] Ex. 1009 (EPA-Proposal) at 4704.

722. Claims 2 and 3 of the '114 Patent recite:

- Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."
- Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."

In addition to the reasons described in Ground F, claims 2 and 3 would have been obvious over Downs-Boiler in view of the EPA-Proposal. As described in Ground F, Downs-Boiler discloses removing at least 77 wt% of the mercury in the mercury-containing gas.[1054] Downs-Boiler also discloses removing mercury to meet advancing EPA standards regulating mercury emissions from coal-fired plants.[1055] The EPA proposed rules stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018" with more near-term caps built in.[1056]

723. A POSITA would have been motivated to target at least this desired level in order to comply with these upcoming federal mercury emissions standards and, as such, would have selected a rate of removing mercury from the mercury containing gas of at least that mandated by the EPA—removing greater than 70% of the mercury from the flue gas. The EPA's announcement of its forthcoming strict

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[1054] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

[1055] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [002].

[1056] Ex. 1009 (EPA-Proposal) at 4698.

regulations that mercury emissions of coal-fired utility boilers must be abated by 70% exerted a strong outside impetus on the industry. As a result, there was a great need to meet or exceed those compliance limits being driven by the governmental regulations that rendered obvious the limitation of removing greater than 70 wt % of the mercury in the mercury-containing gas. Accordingly, a POSITA would have been motivated to target at least this 70% emissions reduction as a "desired level" of mercury removal from the mercury-containing gas.

XXIII. GROUND E: OBVIOUSNESS OF THE '114 PATENT OVER DOWNS-BOILER IN VIEW OF NELSON

724. It is my opinion that Downs-Boiler in view of Nelson renders obvious each of claims 2-4, 18, 24, 29 and 30. Elements and claims not mentioned below are disclosed and/or obvious for the reasons stated above in Ground C above.

A. DISCLOSURE OF DOWNS-BOILER IN VIEW OF NELSON

1. Claims 24 and 30:

725. Claim Limitation 24(c) and Claim 30 recite:

- ". . . the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition" [claim element 24(c)]
- "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury" [claim 30]

As described above for Ground C, the mercury in the flue gas is adsorbed, and thus contacted, with the sorbent to form a mercury/sorbent composition that comprises

the element bromine, the sorbent material, and mercury. Downs-Boiler states that this adsorption occurs "due to the higher reactivity of oxidized mercury with PAC."[1057] In addition to the reasons provided in Ground C and D, related to—forming a "promoted sorbent"—and—forming a "mercury/sorbent composition compris[ing] the element bromine, the sorbent material, and mercury"—the "contacting" limitations would have been obvious in view of Downs-Boiler over Nelson. A POSITA would have understood that at least a portion of the bromine would be available to promote the activated carbon to form a promoted sorbent.

726. The bromine-containing gas in Nelson is explained as acting as a promoter in that it "increase[s] the ability of the carbonaceous substrate [activated carbon] to adsorb mercury and mercury-containing compounds."[1058] When the promoted sorbent is present in the mercury containing flue gas, Nelson describes that the mercury in the mercury-containing gas reacts (and thus contacts) the activated carbon and bonds to it to form a mercury/sorbent composition that contains mercury, halide promoter (bromide), and sorbent (activated carbon). Nelson describes that this takes place for both elemental mercury and oxidized mercury:

> While not intending to be limited by hypothesized chemistry, it appears that in exposing PAC to concentrated bromine gas, a relatively large quantity of the bromine reacts with the carbon, forming surface compounds on the large surface-area of the

[1057] Ex. 1006 (Downs-Boiler) ¶ [0016]; Ex. 1007 (Downs-Boiler-Provisional) IT [0019].

[1058] Ex. 1012 (Nelson) at Abstract; *see also* Ex. 1012 (Nelson) at Claim 1.

> carbon. *When the PAC is then injected into the flue gas, the elemental mercury and oxidized mercury species there appear to react with at least one form of the bromine-carbon surface compounds that were created and are held fast.* When the carbon particles are removed from the flue gas along with the fly ash by the electrostatic precipitator (ESP) or fabric filter, the mercury is removed with them. The mercury sorbents are then disposed of with the fly ash. *Because the mercury has been chemically adsorbed, rather than just physically adsorbed,* the captured mercury appears to be very stable and does not revolatilize or leach.[1059]
>
> Mixing with the flue gas, the *sorbent adsorbs its elemental mercury and oxidized mercury species.*[1060]

Accordingly, in view of Downs-Boiler's disclosure of mercury bromide adsorbing onto activated carbon, and Nelson's description of the mercury-carbon-bromine reaction, a POSITA would have understood that a mercury/sorbent composition would be formed that includes mercury, sorbent, and bromine.

2. Claims 4 and 29:

a. **"wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material." [claim 4]**

b. **"wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent." [claim 29]**

727. In addition to the reasons described in Ground C for claim 4, both claims 4 and 29 would have been obvious over Downs-Boiler in view of Nelson. Nelson

1059 Ex. 1012 (Nelson) at 6:26-41.

1060 Ex. 1012 (Nelson) at 9:35-37

describes preparation of a promoted activated-carbon sorbent formed from about 1 g to about 30 g of bromide per 100 g of sorbent:

> Any level of bromination of carbonaceous substrates appears to increase their mercury-removal performance. While over 30 wt % of Br_2 (g) can be adsorbed into some powdered activated carbons, for example, significant increases in mercury reactivity will be observed with only about 1 wt % Br_2 (g) in the PAC. Greater degrees of bromination do correlate with greater maximum mercury capacities for a particular carbonaceous substrate.[1061]

And, as the Examiner found during prosecution of the '114 patent:

> The Nelson reference discloses optimizing the amount [of bromine] so as to obtain a desired mercury reactivity. It would have been obvious to one having ordinary skill in the art before the invention was made to have modified [Felsvang] to include the promoted sorbent comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material so as to ensure optimum reaction between the halogen and the activated carbon (Nelson paragraph [0054]).[1062]

I agree with the Examiner in this regard. I also note that, as described in the State of the Art, the claimed 1% - 30% bromine range attempts to encompass the well-known upper and lower limits of a workable range of halogenation of activated carbon that would have been revealed through routine experimentation. Claim 4, as described in Ground F, as well as Claim 29, are each merely an attempt to claim a workable range for combining a conventional halogen (bromine) being used in a

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1061 Ex. 1012 (Nelson) at 8:35-42.

1062 Ex. 1026 ('114 Patent File History) at exhibit page 1611 (10/10/2018 Office Action).

conventional way with a conventional sorbent (activated carbon). The claimed range presents nothing more than optimization of "result-effective" variables that would have been obvious to a POSITA. For example, Nelson describes that "significant increases in mercury reactivity will be observed with only about 1 wt % Br_2 (g)," and that more than 30% does not provide much additional benefit in terms of mercury removal.[1063] In addition, and as described above, it was known that bromine was loaded onto carbon sorbents at approximately 30 wt%, such that the activated carbon could not hold significantly more bromine.[1064]

3. <u>Claims 2 and 3:</u>

a. **"comprising removing greater than 70 wt % of the mercury in the mercury-containing gas." [claim 2]**

b. **"comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent." [claim 3]**

728. In addition to the reasons described above in Ground C, Claims 2 and 3 would have been obvious over Downs-Boiler in view of Nelson. For example, as explained above with respect to claim 2, Downs-Boiler illustrates removing at least 77% of the mercury from the mercury-containing gas in Figure 3. Through routine process optimization, a POSITA would have been able to adjust the bromine:sorbent ratio such that at least 70% of the mercury is in the mercury-containing gas is

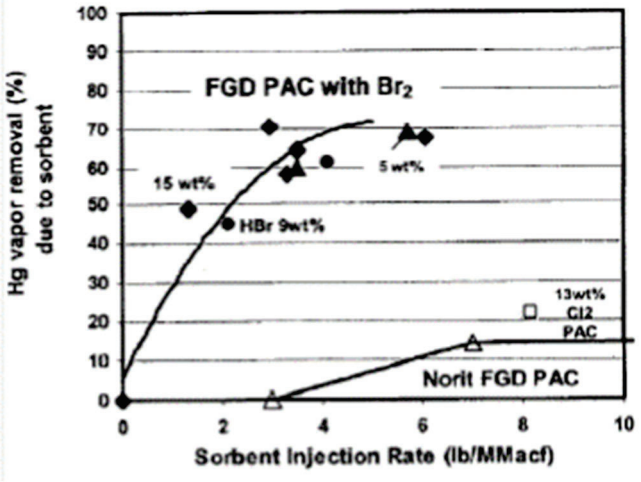
1063 Ex. 1012 (Nelson) at 8:35-40.

1064 State of the Art, § XII.C; Ex. 1042 (Puri) at 260.

removed on the sorbent. Downs-Boiler recognizes that there are a number of factors, such as "combustion air preheater temperature profiles, flue gas composition, fly ash characteristics and composition, and the presence of unburned carbon have all been shown to affect the conversion of elemental mercury to oxidized mercury species."[1065] A POSITA would have looked to Nelson to answer a number of these factors, for example, Nelson also conducted a study to determine the mercury removed by the sorbent itself, as opposed to other components such as unburnt carbon or a scrubber. Figure 15 of Nelson plots the "Hg vapor removal (%) *due to sorbent,"* and the X-axis plots the sorbent injection rate.

Figure 15.

Lausche Plant Duct-Injection ESP Trials



[1065] Ex. 1006 (Downs-Boiler) ll [0005]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ll [006].

At a sorbent injection rate of approximately 4 lb/MMacf, Nelson achieves above 70% removal by the sorbent itself.[1066] And based on the trending curve, a POSITA would have recognized that at a sorbent injection rate of 5 lb/MMacf, the sorbent itself would have removed even more than 70% mercury. Accordingly, a POSITA would have been motivated to, and capable of, using the processes disclosed in Nelson and Downs-Boiler to remove 70% or more mercury from the mercury-containing flue gas, including on the sorbent.

4. Claim 17: "wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of an air pre-heater."

729. In addition to the reasons described above in Ground C, Claim 17 would have been obvious over Downs-Boiler in view of Nelson. Downs-Boiler describes "particulate collectors" including electro static precipitators (ESP) and ***fabric filters (FF)*** that "provide high-efficiency removal of particulate-bound mercury."[1067] Particularly, Downs-Boiler states that "[f]abric filters tend to exhibit better particulate laden mercury removal."[1068] Downs-Boiler discloses that the activated-carbon sorbent is injected into the mercury-containing flue gas such that it is subsequently

[1066] Ex. 1012 (Nelson) at 15:35-38.

[1067] Ex. 1006 (Downs-Boiler) 11 [0003]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [004].

[1068] Ex. 1006 (Downs-Boiler) ¶ [0003]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ill [004].

"removed from the flue gases in a ***downstream particulate collector***,"[1069] as described in Ground E for claim element 25(d). Similarly, Nelson also discloses an embodiment in which "sorbent flows with flue gas to a fabric filter 31 and is deposited on the filter bags in a filter cake along with the fly ash and other gas-stream particulates," which also causes "intimate contact between the sorbents and the remaining mercury in the flue gas."[1070] The "mercury sorbents in the filter cake" are removed, and "[c]leansed of its mercury content and particulates, the flue gas exits the fabric filter."[1071] Accordingly, Nelson clarifies the disclosure of Downs-Boiler, explaining that the activated-carbon sorbent would have been injected upstream of a particulate separator (such as a fabric filter).

730. Downs-Boiler also describes an embodiment in which an electrostatic precipitator (ESP) is used as a particulate separator.[1072] However, Downs-Boiler does not expressly state the injection location of activated-carbon sorbent for such an embodiment. A POSITA would have used the disclosure of Nelson to clarify the disclosure of Downs-Boiler, particularly, where to inject the activated-carbon sorbent for coal-fired utility plant configured with an ESP. Nelson describes injecting

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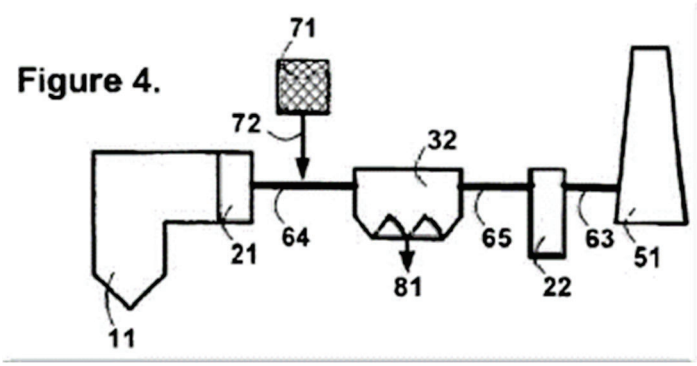
[1069] Ex. 1006 (Downs-Boiler) ¶ [0004] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) 411 [005].

[1070] Ex. 1012 (Nelson) at 9:36-42

[1071] Ex. 1012 (Nelson) at 9:43-50

[1072] Ex. 1006 (Downs-Boiler) ¶ [0003]; *see also* Ex. 1007 (Downs-Boiler-Provisional) III [004].

"sorbents to a plant which has a 'hot-side' ESP, a particularly difficult situation for mercury control.[1073] In this equipment arrangement, the air preheater 22 follows the ESP 32.[1074]



Nelson discloses that in such a configuration, as shown in Figure 4, the activated carbon is injected "from bin 71," which is upstream from the air-preheater (item 22) and upstream from a particulate separator (item 32).[1075] Accordingly, Nelson clarifies the disclosure of Downs-Boiler in that for a plant with a hot-side ESP followed by a pre-heater, the injection of activated carbon would have been upstream of both.

XXIV. GROUND F: ANTICIPATION OF THE '114 PATENT OVER VOSTEEN AND/OR OBVIOUSNESS OVER VOSTEEN ALONE OR IN COMBINATION WITH GRANITE

1073 Ex. 1012 (Nelson) at 10:9-11.
1074 Ex. 1012 (Nelson) at Figure 4, 10:9-13
1075 Ex. 1012 (Nelson) at 10:20-22.

731. It is my opinion that Vosteen either alone or in combination with the background knowledge of a POSITA or Granite renders obvious each of asserted claim of the '114 patent. In my analysis below, I start with claim 25, because it has the fewest limitations.

A. INDEPENDENT CLAIM 25

1. Claim 25: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

732. Vosteen discloses the preamble. The title of Vosteen is, "Process for removing mercury from flue gases."[1076] Flue gas is an example of a mercury-containing gas, and "removing mercury" refers to separating the mercury from a mercury-containing gas. Vosteen describes "removal of mercury from the flue gases in a flue gas emission control system downstream of the combustion," in plants such as "power stations, for example bituminous coal-fired or lignite-fired power stations.[1077] Claim 1 of Vosteen also discloses the preamble, as shown in the highlighting below:[1078]

[1076] Ex. 1008 (Vosteen) at Title.
[1077] Ex. 1008 (Vosteen) at 2:16-20, 2:35-37.
[1078] Ex. 1008 (Vosteen) at Claim 1.

1. Process for removing mercury from mercury-containing flue gases of a furnace within which a combustion or incineration is carried out, wherein

bromine, a bromine compound, a mixture of bromine compounds or a mixture of bromine and a bromine compound or compounds, is fed to the furnace or to the flue gas of the furnace in a plant section downstream of the furnace, or to both the furnace and the flue gas, the temperature during the first contact of the bromine or of said mixture with the flue gas being at least 500° C.,

the combustion or incineration is carried out in the presence of a sulphur compound,

and then the flue gas is subjected to a cleanup for removing mercury from the flue gas.

Subjecting flue gas "to a cleanup for removing mercury from the flue gas" refers to separating mercury from a mercury-containing gas. Claim 18 of Vosteen also discloses the preamble, as shown in the highlighting below.

18. A process for removing mercury from mercury-containing flue gases of a furnace, comprising:

carrying out a combustion or incineration process, within the furnace, in the presence of a sulphur compound;

feeding bromine, a bromine compound, a mixture of bromine compounds, or a mixture of bromine and one or more bromine compounds to at least one of the furnace or a flue gas of the furnace in a plant section downstream from the furnace, a temperature at first contact of the bromine, bromine compound, mixture of bromine compounds, or mixture of bromine and one or more bromine compounds with the mercury-containing flue gas being at least 800° C.; and

subjecting the mercury-containing flue gas to a cleanup for substantially removing mercury from the mercury-containing flue gas, wherein the cleanup for substantially removing mercury from the mercury-containing flue gas includes a dry cleanup stage comprising at least one sorbent, and

2. Claim 25: Element 25(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas:

733. Vosteen discloses this claim element. Vosteen discloses that one of the applications for his process is in removing mercury from a mercury-containing gas generated from the combustion of coal in a combustion chamber. For example, Vosteen describes experiments conducted on "a *coal-fired power station* of Bayer AG in Uerdingen, which essentially consists of *a slag-tap fired boiler* . . "[1079] Vosteen also describes a *"coal-fired* power station of Bayer AG in Uerdingen (see FIG.9)" with "two parallel slag-tap fired boilers 91, 92 having temperatures in the *combustion chamber* around 1450°C."[1080] Vosteen describes his results in Figures 7 and 8 regarding the experiments conducted on "coal combustion (bituminous coal)."[1081] This limitation is also disclosed in claims 1 and 18 of Vosteen, highlighted below:[1082]

[1079] Ex. 1008 (Vosteen) at 7:25-28.
[1080] Ex. 1008 (Vosteen) at 10:63-11:6.
[1081] Ex. 1008 (Vosteen) at 11:23-24.
[1082] Ex. 1008 (Vosteen) at Claims 1, 18.

1. Process for removing mercury from mercury-containing flue gases of a furnace within which a combustion or incineration is carried out, wherein

bromine, a bromine compound, a mixture of bromine compounds or a mixture of bromine and a bromine compound or compounds, is fed to the furnace or to the flue gas of the furnace in a plant section downstream of the furnace, or to both the furnace and the flue gas, the temperature during the first contact of the bromine or of said mixture with the flue gas being at least 500° C.,

the combustion or incineration is carried out in the presence of a sulphur compound,

and then the flue gas is subjected to a cleanup for removing mercury from the flue gas.

18. A process for removing mercury from mercury-containing flue gases of a furnace, comprising:

carrying out a combustion or incineration process, within the furnace, in the presence of a sulphur compound;

* * *

feeding the coal to the furnace,

the process further comprising feeding sulphur, a sulphur compound or a mixture of sulphur compounds to said furnace based on measuring mercury content of the mercury-containing flue gas.

3. Claim 25: Element 25(b)—"wherein the coal comprises added Br_2 HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, a bromide compound, or a combination thereof, or a combination thereof,"

734. Vosteen discloses this claim element. Vosteen describes adding HBr (hydrogen bromide) and bromide compounds to the coal, or to the combustion chamber, or both. Sodium bromide is an example of a bromide compound. Vosteen describes that bromine-containing ingredients are added to the combustion chamber

(also referred to by Vosteen as a furnace), and can also be added to the coal upstream of the combustion chamber.

> The invention relates to a process for removing mercury from flue gases of high-temperature plants, in particular from power stations and waste incineration plants, *in which bromine and/or a bromine compound and/or a mixture of various bromine compounds is* <u>*fed to the if appropriate multistage furnace*</u> and/or to the flue gas in a plant section downstream of the furnace .[1083]
>
> Particularly preferably, an *aqueous solution of hydrogen bromide or an alkali metal bromide,* in particular sodium bromide, or an aqueous solution of the alkali metal bromide is used.[1084]
>
> The <u>*bromine compound*</u>, for example, <u>*sodium bromide, can be added in solid form, for example as salt, or in liquid form,*</u> for example as aqueous solution, <u>*to the*</u> waste mixture, <u>*coal or the like to be burnt, upstream of the furnace*</u>. The addition can also be <u>*made to a plant section upstream of the furnace*</u>, for example a pyrolysis drum, which serves, for example, for the thermal breakdown of co-

1083 Ex. 1008 (Vosteen) at 1:65-2:5.
1084 Ex. 1008 (Vosteen) at 2:58-61.

> incinerated waste materials, or *to a coal mill*. *The compound can also be fed during the combustion process*. . . .*[T] he bromine compound can be introduced*, likewise in solid or liquid form, *into one or both combustion chambers*, for example into the rotary kiln and/or the afterburning chamber. Preferably, an aqueous solution of the compound is *sprayed into one of the combustion chambers*.[1085]
>
> [I]t is also possible to feed the bromine compound, for example an *aqueous solution of hydrogen bromide or sodium bromide*, at a fine dispersion *to the combustion* air and/or if appropriate to a recirculated substream, in particular recirculated flue gas, recirculated ash and recirculated fly ash.[1086]

The "bromine and/or a bromine compound" identified above in Vosteen refers to molecular bromine (Br_2) and/or a compound containing the element bromine (Br) bonded to other chemical elements.

1085 Ex. 1008 (Vosteen) at 4:4-19.

1086 Ex. 1008 (Vosteen) at 4:28-33.

735. This claim element is also disclosed by claims 1 and 2 of Vosteen, highlighted below, which recite adding a bromine compound or mixture of compounds (including hydrogen bromide) to the combustion chamber (furnace):[1087]

1. Process for removing mercury from mercury-containing flue gases of a furnace within which a combustion or incineration is carried out, wherein

bromine, a bromine compound, a mixture of bromine compounds or a mixture of bromine and a bromine compound or compounds, is fed to the furnace or to the flue gas of the furnace in a plant section downstream of the furnace, or to both the furnace and the flue gas, the temperature during the first contact of the bromine or of said mixture with the flue gas being at least 500° C.,

the combustion or incineration is carried out in the presence of a sulphur compound,

and then the flue gas is subjected to a cleanup for removing mercury from the flue gas.

2. Process according to claim 1, wherein the bromine compound is an aqueous solution of hydrogen bromide, an alkali metal bromide, or a mixture thereof.

This claim element is also disclosed by claim 18 of Vosteen, highlighted below:[1088]

18. A process for removing mercury from mercury-containing flue gases of a furnace, comprising:

carrying out a combustion or incineration process, within the furnace, in the presence of a sulphur compound;

feeding bromine, a bromine compound, a mixture of bromine compounds, or a mixture of bromine and one or more bromine compounds to at least one of the furnace

* * *

1087 Ex. 1008 (Vosteen) at Claims 1, 2.

1088 Ex. 1008 (Vosteen) at Claim 18.

wherein feeding the bromine, bromine compound, mixture of bromine compounds, or mixture of bromine and one or more bromine compounds to the furnace comprises:
applying the bromine, bromine compound, mixture of bromine compounds, or mixture of bromine and one or more bromine compounds in an aqueous solution of the bromine, bromine compound, mixture of bromine compounds, or a mixture of bromine and one or more bromine compounds to a coal; and
feeding the coal to the furnace,

4. Claim 25: Element 25(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

736. This claim element is disclosed by Vosteen. Vosteen discloses injecting activated carbon into a mercury-containing flue gas downstream of the combustion chamber and contacting mercury with the sorbent to form a mercury/sorbent composition.

a. Injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber

737. Vosteen discloses a dry-emission control system that includes injecting an activated-carbon sorbent for adsorbing mercury into a mercury-containing gas. Vosteen describes "cloth filters which are impinged with a blown-in finely pulverulent slaked lime/ *activated carbon* or slaked lime/lignite coal coke mixture."[1089]

[1089] Ex. 1008 (Vosteen) at 5:27-30.

738. As I describe in the State of the Art regarding Components Downstream of the Combustion Chamber, fabric filters have been a component of downstream emissions control that contain fabric bags. The mercury-containing flue gas with fly ash pass through the bags, and particle materials are filtered out of the gas. Vosteen describes adding bromine-containing species to the coal (and/or or to the combustion chamber) to introduce HBr and other bromine-containing species into the mercury-containing flue gas generated in the combustion chamber, and also describes injecting a mixture of lime and activated carbon onto fabric filters downstream of the combustion chamber.[1090] This treatment configuration spontaneously brominates the activated carbon (sorbent) in the mercury-containing flue gas as both the activated-carbon sorbent and the bromine-containing species move towards the fabric filter unit. The bromination also occurs in the dust cakes of fly ash, activated carbon, and lime on the outer bag surfaces. In turn, the brominated activated carbon captures elemental and oxidized mercury at extremely high efficiency, due to the large concentration of brominated sites in the activated carbon in a dust cake.

739. Vosteen further describes that the emission control system is downstream of the combustion chamber, in that his process performs the "removal of mercury from the flue gases in a flue gas emission control system downstream of the

[1090] Ex. 1008 (Vosteen) at 5:27-30.

combustion . . . ."[1091] The flue gas was formed as a result of combustion of coal in the combustion chamber.

740. The claims of Vosteen also confirm that the use of the activated-carbon sorbent occurs downstream of the combustion chamber. For example, claim 1 states that "the combustion . . . is carried out . . . *and then* the flue gas is subjected to a cleanup for removing mercury from the flue gas."[1092]

> 1. Process for removing mercury from mercury-containing flue gases of a furnace within which a combustion or incineration is carried out, wherein
>
> bromine, a bromine compound, a mixture of bromine compounds or a mixture of bromine and a bromine compound or compounds, is fed to the furnace or to the flue gas of the furnace in a plant section downstream of the furnace, or to both the furnace and the flue gas, the temperature during the first contact of the bromine or of said mixture with the flue gas being at least 500° C.,
>
> the combustion or incineration is carried out in the presence of a sulphur compound,
>
> and then the flue gas is subjected to a cleanup for removing mercury from the flue gas.

741. It would have also been obvious to combine Vosteen's addition of bromine compounds to coal for combustion with activated carbon injection systems in use at the time that the Vosteen reference was published. For example, Vosteen's bromine additive would have been obvious to use in the plants described in the Granite reference. Granite explains that control technologies for removing mercury

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1091 Ex. 1008 (Vosteen) at 2:17-18.

1092 Ex. 1008 (Vosteen) at Claim 1; *see also* Ex. 1008 (Vosteen) at Claim 12.

from flue gas at the time include the use of activated carbon sorbents injected into the gas stream.[1093] Granite describes, for example, the activated carbon duct injection systems used for mercury control for industrial combustors.[1094] A POSITA would understand that injection of activated carbon downstream of the combustion chamber was the more common and readily available method of using activated carbon for mercury control instead of the impinged fabric filters of Vosteen. Furthermore, a POSITA would have been motivated by Granites teaching that the promotion of activated carbon using halogens such as chlorine and iodine to combine the teachings of Vosteen regarding bromine with the state of the art activated carbon systems it describes.[1095]

b. Contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition

742. The mercury in the flue gas is adsorbed, and thus contacted, with the sorbent to form a mercury/sorbent composition. Vosteen explains that the "dry emission control system" is part of the "flue gas emission control system," and that the dry emission control system works "based on the *adsorption* of ionic mercury compounds."[1096] Vosteen uses the bromine-containing species (such as HBr) to

[1093] Ex. 2003 (Granite 2000) at 1020, 1022.
[1094] Ex. 2003 (Granite 2000) at 1026.
[1095] Ex. 2003 (Granite 2000) at 1020.
[1096] Ex. 1008 (Vosteen) at 5:19-21.

oxidize mercury "since the ionic mercury is readily water soluble . . . and is readily *adsorbable* to a range of adsorbents."[1097] Vosteen discloses that his invention is particularly suited "for those high-temperature plants which do not have a wet flue gas emission control system, but solely have a dry emission control system having a mercury *sorption* stage."[1098] The process that Vosteen repeatedly describes as being performed by the dry-emission control system—"adsorption"—refers to a process by which adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent. In such adsorption processes, the adsorbate (e.g., mercury) is adhering to the sorbent (e.g., activated carbon), and the activated carbon is thus "contacting mercury in the mercury-containing gas," as per claim element 25(c).

743. Vosteen explains that the mercury forms a mercury/sorbent composition that comprises mercury, bromine, and activated carbon. Vosteen states regarding the dry emission control system, "Mercury bromide $HgBr_2$ *adsorbs more strongly to dry sorbents* than mercury chloride $HgCl_2$."[1099] A person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition, because, for example, independent claim 25 of the '114 patent recites a "mercury/sorbent composition" and its dependent claim 30 recites that "the mercury/sorbent composition comprises the

1097 Ex. 1008 (Vosteen) at 2:20-25.
1098 Ex. 1008 (Vosteen) at 5:32-36.
1099 Ex. 1008 (Vosteen) at 5:36-37.

element bromine, the sorbent material, and mercury."[1100] Also, the title of Vosteen is "Process for Removing Mercury from Flue Gases," and the way mercury gets removed from a flue gas, in a dry-sorbent system, is by forming a composition with the sorbent (activated carbon) that is then removed.

744. Vosteen states regarding the dry emission control system that bromine oxidizes mercury to form $HgBr_2$, and "Mercury bromide $HgBr_2$ *adsorbs more strongly to dry sorbents* than mercury chloride $HgCl_2$."[1101] Accordingly, this composition is a "mercury/sorbent" composition, as required in claims 23-25, in that it contains both mercury and sorbent. This composition also comprises the element bromine, the sorbent, and mercury, as required by claim 30. Although this is anticipated as discussed above, these limitations also would have been obvious over Vosteen.

745. Vosteen and Granite each describe "sorbents," and a person of skill in the art would have understood that "sorbents" are used in a process called adsorption. In an adsorption process, adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas." Upon adsorption, the

[1100] Ex. 1001 ('114 Patent) at Claims 25, 30.
[1101] Ex. 1008 (Vosteen) at 2:20-31, 5:35-39.

mercury and activated carbon in the flue gas would form a mercury/sorbent composition.[1102]

746. In addition, a person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition because, for example, independent claim 25 of the '114 patent recites a "mercury/sorbent composition" and its dependent claim 30 recites that "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."[1103]

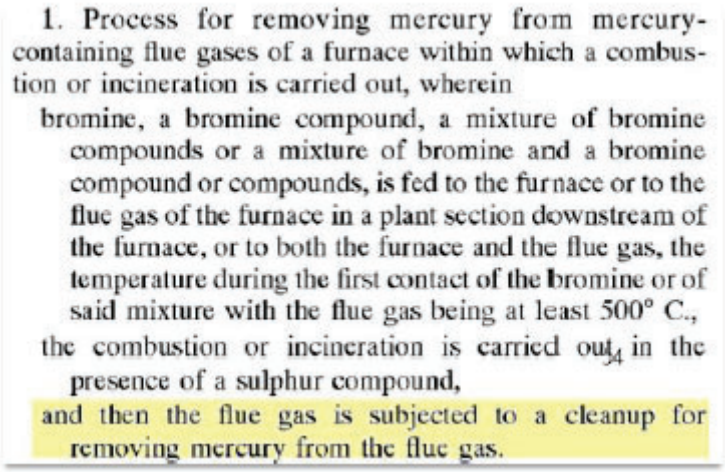
5. Claim 25: Element 25(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

747. Vosteen discloses this claim element. Vosteen describes numerous components that are used to separate the mercury/sorbent composition from the mercury-containing (flue) gas, to form a cleaned gas. Such components include a spray-dryer adsorber (SDA), electrostatic precipitator (ESP), or fabric filter.[1104] These are also discussed in claims of Vosteen:[1105]

> **10.** The process according to claim **8**, wherein said emission control system comprises filtration, electrostatic separation or both.

1102 See, e.g., State of the Art, Sections XII.C.3, XII.G.2.
1103 Ex. 1001 ('114 Patent) at Claims 25, 30.
1104 Ex. 1008 (Vosteen) at 5:15-30.
1105 Ex. 1008 (Vosteen) at Claim 10.

748. Vosteen repeatedly refers to a flue gas *cleaning* system.[1106] Vosteen refers to "clean gas downstream of the wet and/or dry flue gas emission system."[1107] This is because, as Vosteen discloses, an "object of the invention to provide a process for removing mercury, in particular for the substantially complete removal of mercury (Hg)."[1108] The claims of Vosteen further disclose a process of "cleanup" of the flue gas:[1109]



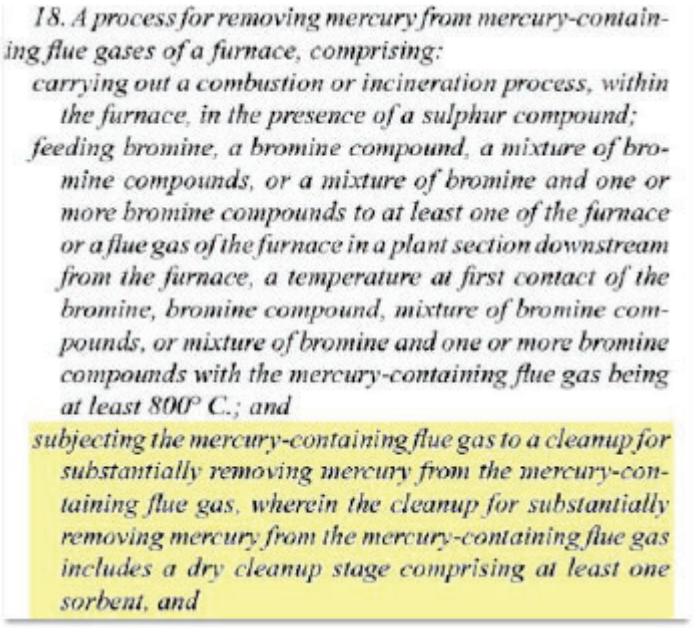
1. Process for removing mercury from mercury-containing flue gases of a furnace within which a combustion or incineration is carried out, wherein

bromine, a bromine compound, a mixture of bromine compounds or a mixture of bromine and a bromine compound or compounds, is fed to the furnace or to the flue gas of the furnace in a plant section downstream of the furnace, or to both the furnace and the flue gas, the temperature during the first contact of the bromine or of said mixture with the flue gas being at least 500° C.,

the combustion or incineration is carried out in the presence of a sulphur compound,

and then the flue gas is subjected to a cleanup for removing mercury from the flue gas.

1106 See, e.g., Ex. 1008 (Vosteen) at Abstract, 2:12-15, 5:1-5.
1107 Ex. 1008 (Vosteen) at 6:2-4.
1108 Ex. 1008 (Vosteen) at 1:50-53.
1109 Ex. 1008 (Vosteen) at Claims 1, 18.



18. A process for removing mercury from mercury-containing flue gases of a furnace, comprising:

carrying out a combustion or incineration process, within the furnace, in the presence of a sulphur compound;

feeding bromine, a bromine compound, a mixture of bromine compounds, or a mixture of bromine and one or more bromine compounds to at least one of the furnace or a flue gas of the furnace in a plant section downstream from the furnace, a temperature at first contact of the bromine, bromine compound, mixture of bromine compounds, or mixture of bromine and one or more bromine compounds with the mercury-containing flue gas being at least 800° C.; and

subjecting the mercury-containing flue gas to a cleanup for substantially removing mercury from the mercury-containing flue gas, wherein the cleanup for substantially removing mercury from the mercury-containing flue gas includes a dry cleanup stage comprising at least one sorbent, and

The "dry cleanup stage" and "dry sorbent" includes, for example, the activated carbon injected into the mercury-containing flue gas that is separated by the fabric filter.[1110] The "cleanup" and "removal" referred to by Vosteen in the passages above refer to separating the mercury/sorbent composition from the mercury-containing flue gas.

749. Granite likewise describes the systems in place at the time as including a particulate collection device.[1111] A POSITA would understand that a particulate collection device would be necessary to remove the particulates in the flue gas, as well as the mercury absorbed on the particulates.

[1110] Ex. 1008 (Vosteen) at 5:27-30.

[1111] Ex. 2003 (Granite 2000) at 1024.

B. CLAIMS DEPENDING FROM CLAIM 25

1. Claim 26: "The method of claim 25, wherein the coal comprises the added Br_2 HBr, the bromide compound or a combination thereof, added to the coal upstream of the combustion chamber."

750. Vosteen discloses this claim. As I explain regarding claim element 25(b), Vosteen describes that bromine-containing ingredients are added to the coal upstream of the combustion chamber. Exemplary bromine-containing ingredients added to the coal are aqueous hydrogen bromide [HBr(aq)], bromide compounds in solid or aqueous form (e.g., sodium bromide [NaBr(s) or NaBr(aq)], molecular bromine (Br_2), and mixtures thereof.

2. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2 HBr the bromide compound, or a combination thereof."

751. Vosteen discloses this claim. As I explain regarding claim element 25(b), Vosteen describes that the combustion chamber (sometimes referred to as "furnace" or "boiler" in Vosteen) comprises added aqueous hydrogen bromide [HBr(aq)], bromide compounds in solid or aqueous form (e.g., sodium bromide [NaBr(s) or NaBr(aq)], molecular bromine (Br_2), and mixtures thereof.

3. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a

combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level."

752. Vosteen discloses this claim element.

a. **Claim Element 28(a)—"monitoring the mercury content of the cleaned gas; and"**

753. Vosteen discloses this claim element. Vosteen describes that "*the mercury content of the flue gas*, in particular the content of metallic [i.e., elemental] mercury, *is measured continuously* downstream of the flue gas emission control system."[1112] Measurements of the mercury content are depicted in Figures 2-8 of Vosteen,[1113] and are also recited in claim 9 of Vosteen:[1114]

> **9**. Process according to claim **8**, wherein the mercury content of the flue gas is measured continuously downstream of the flue gas emission control system and the amount of bromine, bromine compounds fed and any sulphur or sulphur compounds fed is controlled on the basis of the measured mercury content.

Measuring mercury content of the cleaned gas is a form of monitoring the mercury.

b. **Claim Element 28(b)—"controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof"**

1112 Ex. 1008 (Vosteen) at 5:48-50.
1113 Ex. 1008 (Vosteen) at Figs. 2-8.
1114 Ex. 1008 (Vosteen) at Claims 9.

754. Vosteen discloses this claim element. Vosteen monitors the mercury content of the cleaned gas, and in response, controls the rate of addition to the coal and/or combustion chamber of the added bromine-containing species.

> Preferably, in the inventive process, *the mercury content of the flue gas*, in particular the content of metallic mercury, *is measured continuously* downstream of the flue gas emission control system and *on the basis of the measured mercury content the amount of bromine fed and/or bromine compounds and/or the mixture of bromine compounds* and if appropriate sulphur and/or sulphur substances and/or the mixture of sulphur substances *is controlled.*[1115]

As explained above for claim element 25(b), the bromine-containing species include aqueous hydrogen bromide [HBr(aq)], bromide compounds in solid or aqueous form (e.g., sodium bromide [NaBr(s) or NaBr(aq)], molecular bromine (Br_2), and mixtures thereof, and these bromine-containing species are added to either the coal or to the combustion chamber. Claim Element 28(b) is also disclosed by claim 9 of Vosteen:[1116]

> **9**. Process according to claim **8**, wherein the mercury content of the flue gas is measured continuously downstream of the flue gas emission control system and the amount of bromine, bromine compounds fed and any sulphur or sulphur compounds fed is controlled on the basis of the measured mercury content.

1115 Ex. 1008 (Vosteen) at 5:48-55.

1116 Ex. 1008 (Vosteen) at Claims 9.

c. Claim Element 28(c)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

755. Vosteen discloses this claim element. As discussed for claim element 28(a) and 28(b), Vosteen describes measuring the mercury content and then, in response to that measurement, controlling process parameters (e.g., rates of addition of bromine-containing components) to achieve those limits. Measurements of the mercury content are depicted in Figures 2-8 of Vosteen,[1117] and also recited in claim 9 of Vosteen.[1118] Vosteen further describes maintaining mercury content of the cleaned gas below desired levels, including those imposed by regulatory authorities. For example, Vosteen mentions that "strict limiting values exist for the legally permissible emission of mercury, for example from incineration plants and power stations."[1119] Vosteen discusses the need that his invention provided a solution for "further reduction of the currently permitted limiting values" of mercury emissions.[1120] Limiting values and legally required limits for mercury are each examples of a "desired level."

756. As I discuss in the State of the Art, the EPA and other regulatory bodies proposed rules that, upon implementation, would have required mercury emissions

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1117 Ex. 1008 (Vosteen) at Figs. 2-8.
1118 Ex. 1008 (Vosteen) at Claims 9.
1119 Ex. 1008 (Vosteen) at 1:10-13.
1120 Ex. 1008 (Vosteen) at 1:20-22.

reductions by 70%. In trying to ensure their plants were compliant upon eventual implementation and promulgation of the EPA rules, a person of skill in the art would have been motivated, and it would have been obvious, to keep mercury emissions below the desired levels proposed by the EPA in order to avoid paying regulatory fines and other penalties that would incur upon rule implementation.

4. Claim 29: "wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."

757. Claim 29 would have been obvious over Vosteen. In Figure 6 of Vosteen, the Y-axis represents the percentage by weight of elemental mercury (labeled Hg_{met} for metallic mercury) compared to total mercury (labeled Hg_{tot}). On the X-axis, Vosteen plots the total bromine concentration in the mercury-containing gas (Br_{tot}), which is the sharper curve.[1121]

[1121] Ex. 1008 (Vosteen) at 10:58-61.

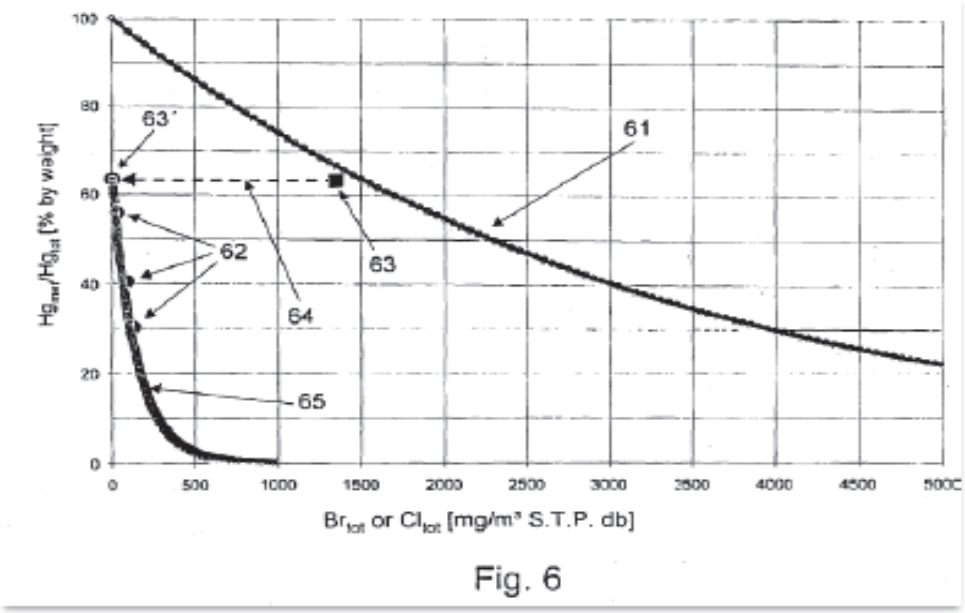


Fig. 6

The values on the X-axis are presented as mg/m^3 S.T.P. db, which is milligrams Br per cubic meter of mercury-containing flue gas, on a dry basis'[1122] at standard temperature (25 °C) and standard pressure (1 atm). Vosteen also describes that activated carbon is used in his system,[1123] but does not expressly state the injection rate of activated carbon into the system downstream of the combustion chamber.

758. A person of ordinary skill in the art would have known to use, or at least start with as a first approximation, widely accepted values for injection rates of activated carbon. As described above,[1124] it was routine in the industry to use injection rates of activated carbon of around 10 pounds/MMacf (million actual cubic

1122 Ex. 1008 (Vosteen) at 1:18.
1123 Ex. 1008 (Vosteen) at 5:23-29, 5:37.
1124 State of the Art, § XII.C.5, XII.G

feet of flue gas) to capture mercury. Based on the data presented by Vosteen of 50 mg bromine per m^3 of flue gas S.T.P. db (the first datapoint described by Vosteen),[1125] and a standard and well-known injection rate of activated carbon of around 10 pounds/MMacf, a person of ordinary skill in the art would have used, or at least tried using, a mercury-containing gas that comprises about 20 grams of the element bromine per 100 grams of sorbent, which is within the claimed range of 1-30 grams bromine per 100 grams sorbent. I explain my calculations below.

759. In order to determine a ratio of bromine concentration in the flue gas to activated carbon in the flue gas, the concentrations must have the same units—such as grams per actual cubic feet or pounds per million actual cubic feet. Vosteen provides the gas-phase concentration of bromine in units of mg/m^3 Standard Temperature and Pressure (STP) dry basis (db). Activated-carbon injection concentrations were typically provided in pounds (lbs.) per million actual cubic feet (MACF) of flue gas. Converting between the two would have been a routine calculation at a power plant to a person of ordinary skill in the art and would have involved such basic concepts as the ideal gas law (to convert concentrations between temperatures and pressures), which was taught in first semester undergraduate chemistry to a person of skill in the art.[1126] Such unit conversion would have also

1125 Ex. 1008 (Vosteen) at 10:37-45.

1126 See, e.g., State of the Art, § XII.A.9.

involved basic engineering knowledge of a power-plant operation, such as a typical flue gas temperature, pressure, and moisture content. Each of these would have been well-known to a person of skill in the art.

760. A person of skill in the art would have known that a typical flue gas has approximately 10% water content by volume. As such, volume on an actual basis equals (volume on a dry basis) / 0.9. A person of ordinary skill in the art would have understood that ten percent is a nominal value for moisture in flue gas because moisture levels diminish for coals of progressively higher rank. It was known, for example, that lignites and subbituminous can produce flue gas with 15 % moisture or greater, and anthracites can produce as little as 5 % moisture or less. [1127] For example, estimates for a low volatile bituminous coal gave 8.1 % moisture in flue gas.[1128]

761. Regarding the second conversion, a person of skill in the art would have understood from the ideal gas law that the density of a gas is proportional to pressure and inversely proportional to temperature. A person of skill in the art would have learned from undergraduate chemistry that standard temperature and pressure (STP) refers to 25 °C (298 K) and 1 atm, respectively, and would have known that a typical

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[1127] Ex. 1027 (B&W Steam) at 8-5 to 8-6.

[1128] Ex. 1008 (Vosteen) at 2:36-38 ("bituminous coal-fired or lignite-fired power stations").

flue gas temperature where sorbent would be injected is 150 °C (413 K) and also 1 atm of pressure. A person of ordinary skill in the art would have understood that this temperature is a typical value for sorbent injection downstream of an air preheater and upstream of an ESP or fabric filter. A POSITA would have known that air preheaters typically do not operate with outlet gas temperatures below the acid dew points of sulfuric acid, which are given as 120 —150 °C[1129] This dewpoint range restricts the outlet temperatures to somewhat hotter values like 150 °C. Last, a person of ordinary skill in the art would have found in readily available tables of unit conversions that 1 m^3 = 35.3^6 ft^3.

762. Accordingly, 50 mg / m^3 S.T.P. db (as disclosed by Vosteen) converts to the following in terms of grams bromine / million actual cubic feet.

$$\frac{50\ mgBr}{m^3_{STP.DB}} \times \left(\frac{0.9m^3_{STP.DB}}{1.0m^3_{STP}}\right) \times \left(\frac{1g}{1000\ mg}\right) \times \left(\frac{1\ atm}{1\ atm}\right) \times \left(\frac{298K}{413K}\right) \times \left(\frac{1m^3}{35.3ft^3}\right)$$
$$\times \left(\frac{10^6 ACF}{1\ MACF}\right) \times 919.8 \frac{g\ Br}{MACF}$$

763. A person of ordinary skill in the art would have also been readily able to convert pounds activated carbon to grams activated carbon through the well-known unit conversion that there are 453.592 grams per pound. Accordingly, at a typical

[1129] Ex. 1027 (B&W Steam) at 19-11.

activated-carbon injection rate of 10 pounds per MACF, the injection rate of activated carbon would equal:

$$10\frac{pounds\ PAC}{MACF} \times \frac{453.592\ grams}{pounds} = 4{,}535\frac{grams\ Activated\ Carbon}{MACF}$$

Dividing the two injection rates provides a mercury-containing gas that comprises about 20 grams bromine per 100 grams of activated-carbon sorbent, which is within the range of 1 gram to 30 grams.

764. Claim 29 is merely an attempt to claim a workable range for combining a conventional halogen (bromine) being used in a conventional way (to oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing in the '114 patent specification attributes significance to the claimed range, or establishes that the claimed range "achieves unexpected results." The range presents nothing more than optimization of "result-effective" variables that would have been obvious to a POSITA.

5. Claim 30: "The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

765. Vosteen discloses this claim element. As described above for claim element 25(c), Vosteen discloses that mercury in the flue gas is oxidized by the bromine-containing species, and adsorbed onto activated carbon. Vosteen uses the bromine-containing species (such as HBr) to provide "essentially complete . . oxidation of the mercury," and that the "ionic mercury is readily water soluble . . .

and is readily *adsorbable* to a range of adsorbents."[1130] Vosteen explains that the mercury forms a composition that comprises the element bromine, the sorbent material, and mercury: "Mercury bromide $HgBr_2$ adsorbs more strongly to dry sorbents than mercury chloride $HgCl_2$."[1131] Also, the title of Vosteen is "Process for Removing Mercury from Flue Gases" and the way mercury gets removed from a flue gas, in a dry-sorbent system, is by forming a composition with the sorbent (activated carbon) and bromine-containing species.

C. INDEPENDENT CLAIM 23

766. As shown in the redline below, claim 23 is nearly identical to claim 25, with minor changes.

~~25~~23. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.

Accordingly, my analysis provided for claim 25 applies to claim 23.

1130 Ex. 1008 (Vosteen) at 2:20-31.
1131 Ex. 1008 (Vosteen) at 5:35-39.

1. Claim 23: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

767. The language of the preamble of claim 23 is identical to the preamble of claim 25. Accordingly, the explanation I provide above for the preamble of claim 25 applies equally to the preamble of claim 23.

2. Claim 23: Element 23(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas,"

768. The language of claim element 23(a) is identical to the language of claim element 25(a). Accordingly, the explanation I provide above for claim element 25(a) applies equally to claim element 23(a).

3. Claim 23: Element 23(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br-, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br- or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br-, or a combination thereof, or a combination thereof."

769. The language of claim element 23(b) is similar to the language of claim element 25(b), and I refer to my discussion of that claim element. Claim 23(b) has the following changes, as compared to claim 25(b):

wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br-, or a combination thereof,

wherein the coal comprises added Br_2, HBr, Br-~~, a bromide compound,~~ or a combination thereof, added to the coal upstream of the combustion chamber,

or the combustion chamber comprises added Br_2, HBr, Br-, ~~a bromide compound,~~ or a combination thereof,

or a combination thereof;

770. Claim Element 23(b) is disclosed by Vosteen. The claim recites express examples of chemicals that qualify as halogen or halide promoters—"a halogen or halide promoter comprising HBr, Br-, or a combination thereof"—and Vosteen discloses these express examples. As described above for Claim Element 25(b), Vosteen discloses adding to the combustion chamber and/or coal aqueous hydrogen bromide [HBr(aq)], bromide compounds in solid or aqueous form (e.g., sodium bromide [NaBr(s) or NaBr(aq)], molecular bromine (Br_2), and mixtures thereof). Vosteen also discloses adding a bromide ion (Br^-) to the coal and to the combustion chamber in the form of aqueous solutions of hydrogen bromide and sodium bromide, each of which dissociates in water to form bromide ions.[1132] Thus, Vosteen discloses HBr, and aqueous sodium bromide dissociates in water to form Br^-. When bromine-containing species (e.g., HBr) and carbon come into contact with each other, the bromide acts as a promoter.[1133]

771. For example, Vosteen describes applying aqueous hydrogen bromide (HBr) to the coal and into the combustion chamber, and at combustion temperatures (much greater than the boiling point of water), the HBr evaporates into the gas phase,

1132 Ex. 1008 (Vosteen) at 2:55-61, 4:4-19, 4:27-33.

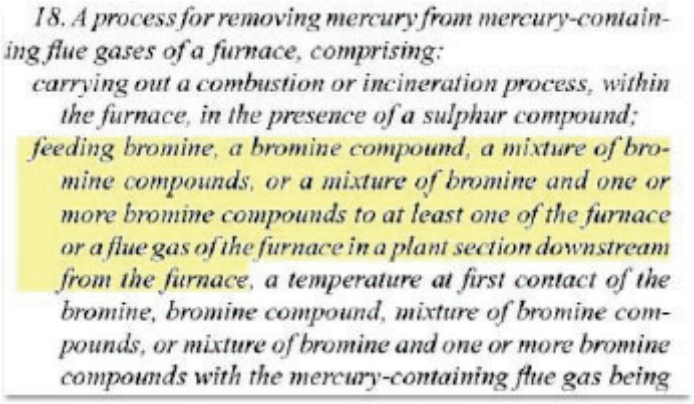
1133 See, e.g., State of the Art, Sections XII.C.3, XII.G.2.

such that the mercury-containing gas also includes HBr. Vosteen further describes that the mercury-containing gas contains a halogen or halide promoter (e.g., bromine-containing species). For example, Figures 2, 5, 6, and 8 of Vosteen each display the concentration of bromine and mercury in the flue gas.[1134] Vosteen confirms that bromine-containing species are present in the mercury-containing gas, stating "that the mass ratio of bromine to mercury in the flue gas is in the range from 10^2 to 10^4."[1135] Vosteen further states that the bromine or bromine compound is added "to a recycled flue gas stream."[1136]

> **5**. Process according to claim **1**, wherein the bromine, the bromine compound or the mixture is added to combustion air supplied to the furnace, to a recycled flue gas stream, a recycled fly ash or any combination thereof.

A recycled flue gas stream is an example of a mercury-containing gas. Claim 18 of Vosteen also describes that the mercury-containing (flue gas) includes the bromine-containing species:[1137]

1134 Ex. 1008 (Vosteen) at 6:15-20, 6:35-45, 6:54-60 (describing Figures 2, 5, 6, and 8).
1135 Ex. 1008 (Vosteen) at Claim 6.
1136 Ex. 1008 (Vosteen) at Claim 5.
1137 Ex. 1008 (Vosteen) at Claim 18.



18. A process for removing mercury from mercury-containing flue gases of a furnace, comprising:

carrying out a combustion or incineration process, within the furnace, in the presence of a sulphur compound;

feeding bromine, a bromine compound, a mixture of bromine compounds, or a mixture of bromine and one or more bromine compounds to at least one of the furnace or a flue gas of the furnace in a plant section downstream from the furnace, a temperature at first contact of the bromine, bromine compound, mixture of bromine compounds, or mixture of bromine and one or more bromine compounds with the mercury-containing flue gas being

4. Claim 23: Element 23(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

772. The language of claim element 23(c) is identical to the language of claim element 25(c). Accordingly, the explanation I provide above for claim element 25(c) applies equally to claim element 23(c).

5. Claim 23: Element 23(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

773. The language of claim element 23(d) is identical to the language of claim element 25(d). Accordingly, the explanation I provide above for claim element 25(d) applies equally to claim element 23(d).

D. INDEPENDENT CLAIM 24

774. As shown in the redlines below, claim 23 is nearly identical to claims 25 and 28, with minor changes.

~~25~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, or

a combination thereof~~,~~;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition; ~~and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~.~~;

~~28. The method of claim 25, further comprising~~

monitoring the mercury content of the cleaned gas; and

controlling, in response to the mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or

a combination thereof,

so that the mercury content of the cleaned gas is maintained at or below a desired level.

Claim 24 combines limitations of claim 23 ("wherein the mercury-containing gas comprises ...), and claims 25 and 28. For the same reasons Vosteen discloses claims 23, 25, and 28, it also discloses claim 24. Accordingly, my analysis provided for claims 24, 25, and 28 also applies to claim 23.

1. Claim 24: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

775. The language of the preamble of claim 24 is identical to the preamble of claim 23 [which is identical to the preamble of claim 25]. Accordingly, the explanation I provide above for the preambles of claims 25 and 23 applies equally to the preamble of claim 24.

2. Claim 24: Element 24(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas,"

776. The language of claim element 24(a) is identical to the language of claim element 23(a) [which is identical to claim element 25(a)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 24(a).

3. Claim 24: Element 24(b)—"wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2 HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof."

777. The language of claim element 24(b) is identical to the language of claim element 23(b). Accordingly, the explanation I provide above for claim element 23(b) applies equally to claim element 24(b).

4. Claim 24: Element 24(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the

activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;"

778. The language of claim element 24(c) is similar to the language of claim element 23(c) [which is identical to the language of claim element 25(c)], and I refer to my discussion of those claim elements. Claim element 24(c) has the following changes:

> injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;
>
> contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition; ~~and~~"

The limitations added to claim 24(c) are disclosed because a mercury/sorbent/bromine composition is formed. In particular, Vosteen describes that a mercury/sorbent/bromine composition is formed (which thus includes a mercury/sorbent composition), in that the "mercury bromide ($HgBr_2$) adsorbs to the activated carbon."[1138] When bromine and carbon come into contact with each other,(e.g., upon adsorption as in Vosteen), a POSITA would have understood that the two react with one another and a promoted sorbent is formed.[1139]

1138 Ex. 1008 (Vosteen) at 5:35-39.

1139 See, e.g., State of the Art, Sections XII.C.3, XII.G.2.

779. By 2003, it was well-known that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[1140] A POSITA would have known that the introduction of halogens helped remove mercury by increasing the ability of the activated carbon to bind with the mercury. Thus, a POSITA would have known that the sorbent/halogen complex would have been referred to as a "promoted" sorbent.

5. Claim 24: Element 24(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

780. The language of claim element 24(d) is identical to the language of claim element 23(d) [which is identical to the language of claim element 25(d)]. Accordingly, the explanation I provide above for those claim elements applies equally to claim element 24(d).

6. Claim 24: Element 24(e)—"monitoring the mercury content of the cleaned gas; and"

781. The language of claim element 24(e) is identical to the language of claim 28(a). Accordingly, the explanation I provide above for claim element 28(a) applies equally to claim element 24(e).

7. Claim 24: Element 24(f)(1)—"controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the

[1140] Ex. 1062 (Crocker) at 2-3.

added Br_2 HBr, the bromide compound, or a combination thereof, or a combination thereof,"

782. The language of claim element 24(f)(1) is identical to the language of claim element 28(b). Accordingly, the explanation I provide above for claim element 28(b) applies equally to claim element 24(f)(1).

8. Claim 24: Element 24(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

783. The language of claim element 24(f)(2) is identical to the language of claim element 28(c). Accordingly, the explanation I provide above for claim element 28(c) applies equally to claim element 24(f)(1).

E. INDEPENDENT CLAIM 1

784. As shown in the redlines below, claim 1 is nearly identical to claims 23 and 25/28, with minor changes.

~~25~~1. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, ~~a bromide compound~~Br^-, or a combination thereof, or

a combination thereof~~;~~,

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; ~~and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~.~~,

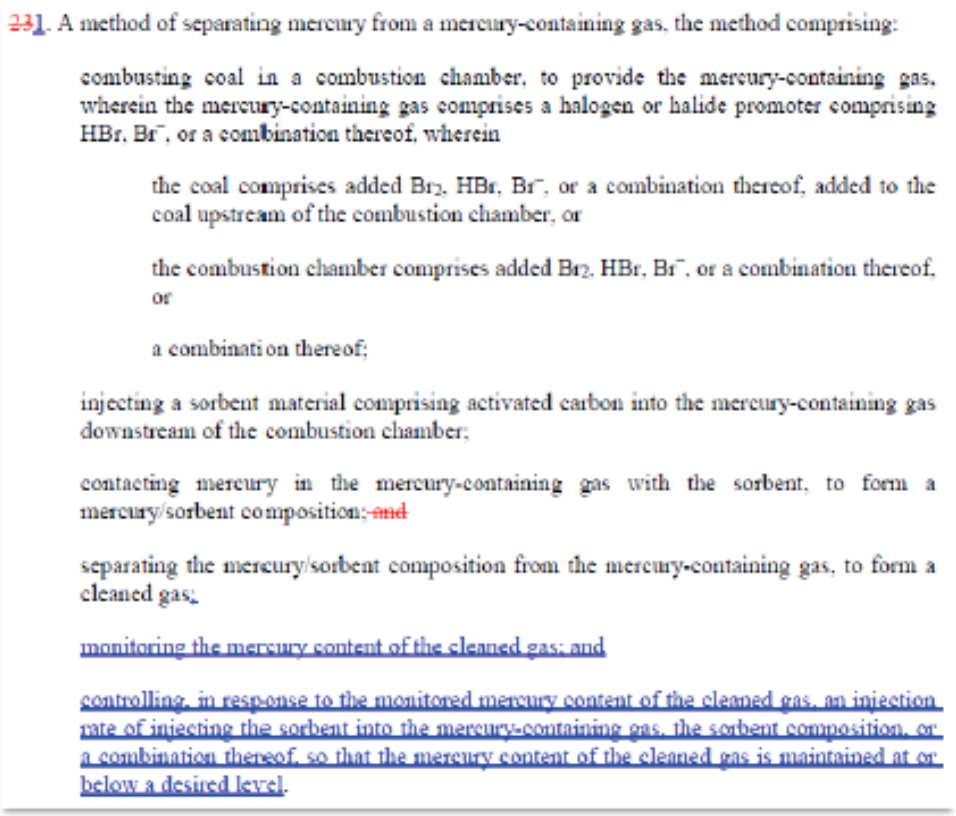
~~28. The method of claim 25, further comprising~~

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas,

~~a rate of addition to~~ the ~~coal or the combustion chamber of the added Br_2, HBr, the bromide compound~~sorbent composition, or a combination thereof, ~~or~~

~~a combination thereof,~~ so that the mercury content of the cleaned gas is maintained at or below a desired level.



~~23~~1. A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein

the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or

the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or

a combination thereof;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; ~~and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.

Accordingly, my analysis provided for claims 23, 24, 25, and 28—in Grounds A and B—also applies to claim 1. As discussed in Ground A and Ground B, Vosteen anticipates and also renders obvious these claims. Claim 1 differs from these claims in that the mercury content must be controlled in response to either: the sorbent injection rate, the sorbent composition, or both. This additional limitation would have been obvious for the reasons discussed below.

1. Claim 1: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

785. The language of the preamble of claim 1 is identical to the preamble of claim 25 [which is identical to the preamble of claims 23 and 24]. Accordingly, the

explanation I provide above in Ground A for the preambles of claims 23-25 applies equally to the preamble of claim 1.

2. Claim 1: Element (1)(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas,"

786. The language of claim element 1(a) is identical to the language of claim element 25(a) [which is identical to claim elements 23(a) and 24(a)]. Accordingly, the explanation I provide above in Ground A for those claim elements applies equally to claim element 1(a).

3. Claim 1: Element (1)(b)—" wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br^-, HBr, Br, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2 HBr, Br^-, or a combination thereof, or a combination thereof:"

787. The language of claim element 1(b) is identical to the language of claim element 23(b) [which is identical to claim element 24(b) and similar to claim element 25(b)]. Accordingly, the explanation I provide above in Ground A and in Ground B ("Claims 23-30") for those claim elements applies equally to claim element 1(b).

4. Claim 1: Element (1)(c)—" injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition:"

788. The language of claim element 1(c) is identical to the language of claim element 25(c) [which is identical to claim element 23(c) and similar to claim element 24(c)]. Accordingly, the explanation I provide above in Ground A and in Ground B ("Claims 23-30") for those claim elements applies equally to claim element 1(c).

5. Claim 1: Element (1)(d)—" separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

789. The language of claim element 1(d) is identical to the language of claim element 23(d) [which is identical to the language of claim elements 24(d) and 25(d)]. Accordingly, the explanation I provide above in Ground A for those claim elements applies equally to claim element 1(d).

6. Claim 1: Element (1)(e)—" monitoring the mercury content of the cleaned gas; and"

790. The language of claim element 1(e) is identical to the language of claim 28(a) [which is identical to the language of claim element 24(e)]. Accordingly, the explanation I provide above in Ground A for those claim elements applies equally to claim element 1(e).

7. Claim 1: Element (1)(f)(1)—" controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof."

791. As discussed above in Ground A for Claim Element 28(b), Vosteen continuously monitors the mercury content of the cleaned gas, and, in response,

continuously adjusts the rate of addition to the coal or combustion chamber of the added bromine-containing species.'[1141] The bromine-containing species include aqueous hydrogen bromide [HBr(aq)], bromide compounds in solid or aqueous form (e.g., sodium bromide [NaBr(s) or NaBr(aq)], molecular bromine (Br_2), and mixtures thereof, and these bromine-containing species are added to either the coal or to the combustion chamber.

792. A POSITA would have understood that adjusting the rate of addition of bromine-containing species would have affected the sorbent composition (e.g., the amount of bromine and/or adsorbed mercury on the sorbent). A POSITA reviewing the figures of Vosteen would have known to use the monitored mercury content to control the injection rate of bromine-containing promoter, and thereby controlled the activated-carbon sorbent composition, in response to the monitored mercury content of the cleaned gas. Therefore, A POSITA would have known that by controlling the feed rate of bromine-containing species, the sorbent composition in the mercury-containing gas would have also been controlled.

793. As discussed previously, a POSITA would have known that activated carbon was expensive, especially relative to costs of components such as HBr or sodium bromide. Thus, a POSITA would have been motivated to adjust the addition rate of bromine-containing species to remove sufficient mercury while minimizing

[1141] Ex. 1008 (Vosteen) at 5:48-55, Claim 9.

the sorbent injection rate. A POSITA viewing the figures of Vosteen (e.g., Figs. 58) showing bromine injection versus mercury removal would have been motivated, and thus it would have been obvious, to at least try using the charts to control the sorbent injection rate at a level that minimized costs while reaching mercury removal targets. Furthermore, due to the variability of the composition of coal as a fuel source (including for example, native mercury and halogen content), as described in the State of the Art,[1142] it would have been obvious that some amount of adjustment to the rate of injection of the sorbent into the flue gas would be performed as part of routine process control and optimization to account for variances in the coal.

8. Claim 1: Element (1)(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

794. The language of claim element 1(f)(2) is identical to the language of claim element 28(c). Accordingly, the explanation I provide above in Ground A and in Ground B ("Claims 23-30") for claim element 28(c) applies equally to claim element 1(f)(2).

F. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: "removing greater than 70 wt % of the mercury in the mercury-containing gas."

795. Vosteen discloses this element. For example, Vosteen describes "an object of the invention to provide a process for removing mercury, in particular for

[1142] State of the Art, § XII.B.1.

the substantially complete removal of mercury (Hg), from flue gases of high-temperature processes."[1143] In one example involving industrial wastewater incineration, which was known to have even more mercury than coal combustion, Vosteen was able to remove more than 99.9% of total mercury.[1144] Shown in Figure 5, reproduced below, Vosteen discloses removing more than 98% of the mercury from the mercury-containing gas.[1145]

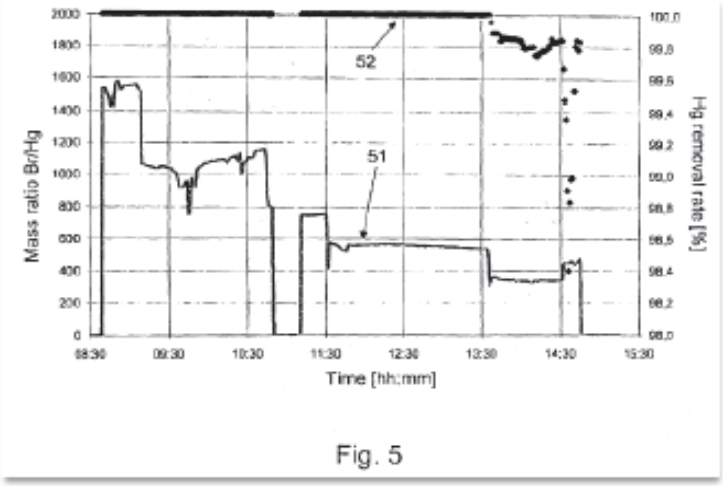


Fig. 5

The Y-axis on the right is labeled "Hg removal rate [%]."[1146] Vosteen explains that using his processes, with injection of bromine, "the mercury content in the flue gas markedly decreases with addition of the bromine compound."[1147]

1143 Ex. 1008 (Vosteen) at 1:50-52.
1144 Ex. 1008 (Vosteen) at 8:22-38.
1145 Ex. 1008 (Vosteen) at Figure 5.
1146 Ex. 1008 (Vosteen) at 6:35-40 (describing Figure 5).
1147 Ex. 1008 (Vosteen) at 11:57-60.

796. In addition to the mercury removal percentages disclosed by Vosteen, Claim 2 of the '114 patent would have been obvious to a person of skill in the art in that Vosteen discloses removing sufficient mercury to comply with legal and regulatory requirements.[1148] As described in the State of the Art regarding EPA Regulations,[1149] a person of skill in the art would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations requiring 70% mercury removal, including EPA's Clean Air Mercury Rule (CAMR). Notice of these regulations exerted a strong outside impetus on the industry to evaluate control schemes to comply with the regulations' eventual implementation. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

2. Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."

797. Claim 3 would have been obvious to a person of skill in the art over Vosteen. For example, as described for Claim 2 above, Vosteen discloses removing more than 98% of the mercury from the mercury-containing gas.[1150]Vosteen discloses

1148 Ex. 1008 (Vosteen) at 1:10-13, 1:20-22.
1149 State of the Art, XII.D – XII.F.
1150 Ex. 1008 (Vosteen) at 6:35-40 (describing Figure 5).

that his invention is particularly suited "for those high-temperature plants *which do not have a wet flue gas emission control system*, but solely have a dry emission control system having a mercury *sorption* stage."[1151] Such plants with "solely" a dry emission control system, and without a scrubber, would be dependent on the activated carbon for mercury removal. Moreover, the Hg removals on sorbents alone would meet or exceed the 70% removal threshold under the configurations disclosed by Vosteen. Specifically, Vosteen discloses that "lignite-fired power stations"[1152] would benefit from his Hg control methods. A person of ordinary skill in the art would have understood that such plants typically have very low concentrations of inherent chlorine in their flue gas as well as very low LOT levels in their flyash. Under such circumstances, Hg capture on inherent unburned carbon is minimal. Consequently, a person of ordinary skill in the art would have understood that adding bromine to the furnace of a plant with "solely" a dry emission control system, and without a scrubber, while injecting a sorbent ahead of the particle collection device, as Vosteen teaches, ensures that virtually all the Hg captured in a particle collection device would be bound to the sorbent. Furthermore, Vosteen also teaches how to adjust the bromine addition level to achieve Hg removal up to essentially complete removal, including 70 % removal.

1151 Ex. 1008 (Vosteen) at 5:32-36.

1152 Ex. 1008 (Vosteen) at 2:36-37.

798. As described in the State of the Art,[1153] a person of skill in the art would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations surrounding announced regulations requiring 70% mercury removal, such as the EPA's Clean Air Mercury Rule (CAMR). Notice of these regulations exerted a strong outside impetus on the industry to adjust processes to comply with the regulations' eventual implementation. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate in a plant he described as preferred (one that relied solely on a dry emission control system having a mercury sorption stage) to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

3. Claim 4: "The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material."

799. This claim would have been obvious over Vosteen. Claim 4 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular

[1153] State of the Art, XII.D —XII.F.

range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would have led to an unexpected result from what was already known to one of skill in the art.

800. As described in the State of the Art,[1154] it was known that the saturation limit of activated carbon for bromine (i.e., how much bromine the activated carbon can actually adsorb at equilibrium), was up to 31 to 38 grams per 100 grams of activated carbon. Given the residence times in flue gas, and other inefficiencies, a person of ordinary skill in the art would have understood that the actual bromine loaded onto activated carbon would have been less than the saturation limit.

801. A person of ordinary skill in the art would have recognized that there would have been sufficient bromine in the flue gas, according to Vosteen's processes, to provide a ratio of between 1 g to 30 g of bromine per 100 g of activated carbon. A person of ordinary skill in the art operating a plant with solely a dry emission control system (i.e., without a wet scrubber), would have been motivated to seek to load the activated carbon with up to nearly its saturation limit, because it was known in the art that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[1155] Vosteen expressly discloses the former,[1156] and the latter was well-known in the art.

1154 State of the Art, § XII.C.3.

1155 Ex. 1062 (Crocker) at 2-3.

1156 Ex. 1008 (Vosteen) at 4:46-50.

802. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to achieve halide promoter on the activated-carbon sorbent from about 1 g to about 30 g.

4. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

803. Vosteen discloses this limitation for the reasons discussed in Ground A for Claim Element 25(b) and Claim 27. Vosteen describes that the combustion chamber (sometimes referred to as "furnace" or "boiler" in Vosteen) comprises aqueous hydrogen bromide [HBr(aq)], bromide compounds in solid or aqueous form (e.g., sodium bromide [NaBr(s) or NaBr(aq)], molecular bromine (Br_2), and mixtures thereof), each of which is a halide promoter. Also, as described in Ground A, Claim Element 25(b) and Claim 23, Vosteen discloses adding "free . . . bromine" (Br_2), "hydrogen bromide" (HBr) and "sodium bromide" to the combustion chamber.[1157] HBr and Br^- (e.g., from the dissociated sodium bromide) are expressly disclosed by claims 1 and 23 as examples of "a halogen or halide promoter."

5. Claim 6: "The method of claim 1, wherein the coal comprises added Br_2 HBr. Br, or a combination thereof added to the coal upstream of the combustion chamber."

[1157] Ex. 1008 (Vosteen) Claim 5, 2:55-61, 4:4-33.

804. The language of claim 6 is similar to the language of claim 26, and I refer to my discussion of claim 26 in Ground A. Claim 6 has the following changes, as compared to claim 26:

> wherein the coal comprises ~~the~~ added Br_2, HBr, Br-, ~~the bromide compound~~ or a combination thereof, added to the coal upstream of the combustion chamber

Claim 6 is disclosed, as discussed for claim 26 in Ground A, exemplary bromine-containing ingredients added to the coal are aqueous hydrogen bromide [HBr(aq)], molecular bromine (Br_2), alkali bromides (such as sodium bromide [NaBr(aq)], and mixtures thereof). Vosteen also discloses adding a bromide ion (Br^-) to the coal in the form of aqueous solutions of hydrogen bromide and sodium bromide, each of which dissociates in water to form bromide ions.[1158]

6. Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."

805. Vosteen discloses this limitation for the reasons described in Ground A for Claim Element 25(b) and 26, and as described for Claim Elements 23(b) and 24(b) in Ground A and Ground B. Vosteen describes injecting aqueous hydrogen bromide and aqueous sodium bromide.[1159] Vosteen also discloses a "temperature during contact of the bromine compound with the flue gas being at least 500 °C, preferably

[1158] Ex. 1008 (Vosteen) at 2:55-61, 4:4-19, 4:27-33.
[1159] Ex. 1008 (Vosteen) at 2:55-61, 4:4-19, 4:27-33.

800 °C."[1160] The boiling point of water is around 100 °C, so a POSITA would have understood, or at the very least found it obvious, that introduction of aqueous promoter (such as the aqueous hydrogen bromide or aqueous sodium bromide) would have vaporized into gaseous form. Furthermore, Vosteen describes injecting "free . . . bromine" (Br_2).[1161] The promoter would have remained in the gaseous form as it is transported with the flue gas and eventually contacted the activated-carbon sorbent.

7. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

806. This limitation is disclosed by Vosteen. As discussed above for claim element 1(c), Vosteen discloses activated carbon as a sorbent. Vosteen further specifies "granulated activated carbon" as the sorbent.[1162] A person of skill in the art would have recognized that "granular" activated carbon and "granulated" activated carbon are two words for the same material.

8. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

807. This claim is disclosed by Vosteen. As discussed for claim element 1(b), Vosteen discloses adding the bromine-containing species to a combustion chamber. Vosteen further specifies that the bromine-containing species "can be added after

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1160 Ex. 1008 (Vosteen) at Abstract, 2:7-8, 4:1-4, 4:20-23, Claim 13.
1161 Ex. 1008 (Vosteen) at 2:55-61, 4:4-19, 4:27-33.
1162 Ex. 1008 (Vosteen) at 5:24-25.

combustion, for example in a downstream waste-heat boiler."[1163] Vosteen further refers to "boiler flue gas" in reference to the figures.[1164] Vosteen explains that the boilers are part of the combustion chamber: "The power station [of Figure 9] comprises two parallel slag-tap fired boilers 91, 91' having temperatures in the combustion chamber around 1450 °C. The slag-tap fired boilers 91, 91' are charged with coal 92, 92'."[1165]

9. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

808. This claim is disclosed by Vosteen. For example, the title of Vosteen is "Process for Removing Mercury from Flue Gases," and the Abstract refers to "removing mercury from flue gases of high-temperature plants, in particular power stations."[1166] This element is also disclosed by the claims of Vosteen:[1167]

1163 Ex. 1008 (Vosteen) at 4:20-21; see also Ex. 1008 (Vosteen) at 7:5-8.

1164 Ex. 1008 (Vosteen) at 11:11; see also Ex. 1008 (Vosteen) at 6:15-62, Figure 9.

1165 Ex. 1008 (Vosteen) at 11:3-6.

1166 Ex. 1008 (Vosteen) at Title, Abstract.

1167 Ex. 1008 (Vosteen) at Claims 1, 18.

1. Process for removing mercury from mercury-containing flue gases of a furnace within which a combustion or incineration is carried out, wherein

bromine, a bromine compound, a mixture of bromine compounds or a mixture of bromine and a bromine compound or compounds, is fed to the furnace or to the flue gas of the furnace in a plant section downstream of the furnace, or to both the furnace and the flue gas, the temperature during the first contact of the bromine or of said mixture with the flue gas being at least 500° C.,

the combustion or incineration is carried out in the presence of a sulphur compound,

and then the flue gas is subjected to a cleanup for removing mercury from the flue gas.

18. A process for removing mercury from mercury-containing flue gases of a furnace, comprising:

carrying out a combustion or incineration process, within the furnace, in the presence of a sulphur compound;

feeding bromine, a bromine compound, a mixture of bromine compounds, or a mixture of bromine and one or more bromine compounds to at least one of the furnace or a flue gas of the furnace in a plant section downstream from the furnace, a temperature at first contact of the bromine, bromine compound, mixture of bromine compounds, or mixture of bromine and one or more bromine compounds with the mercury-containing flue gas being at least 800° C.; and

subjecting the mercury-containing flue gas to a cleanup for substantially removing mercury from the mercury-containing flue gas, wherein the cleanup for substantially removing mercury from the mercury-containing flue gas includes a dry cleanup stage comprising at least one sorbent, and

10. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

809. Vosteen discloses claims 18. Vosteen describes a fabric filter ("cloth filter"), which is an example of a particulate separator. Vosteen discloses that the activated-carbon sorbent is injected upstream of the fabric filter, in that the fabric

filter separates the mercury-sorbent composition from the gas stream,[1168] as described in Ground A for claim element 25(d). Vosteen also discloses that the "dry cleanup" (fabric filter) can be used in conjunction with a "wet scrubber."[1169] A person of ordinary skill in the art would have understood that a scrubber is one of the last units in an emissions control system, as shown in item 97 of Figure 9,[1170] and that activated sorbent would have been injected before the scrubber.

810. Likewise, a POSITA combing the teachings of Vosteen with activated carbon injection systems available at the time would find it obvious to use a particular collection device or scrubber downstream from the addition of the activated carbon, in order to remove the activated carbon and the pollutants absorbed thereto, which is the purpose of using activated carbon. Granite explains that control technologies for removing mercury from flue gas at the time include the use of activated carbon sorbents injected into the gas stream ahead of particulate collection devices.[1171]

11. Claim 20: "The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr Br^-, or a combination thereof."

[1168] Ex. 1008 (Vosteen) at 5:24-29.
[1169] Ex. 1008 (Vosteen) at Abstract.
[1170] Ex. 1008 (Vosteen) at 11:1-14, Figure 9.
[1171] Ex. 2003 (Granite 2000) at 1020, 1022, 1024.

811. Vosteen discloses this claim. The language of claim 20 is similar to the language of claim 27, and I refer to my discussion of that claim. Claim 20 has the following changes, as compared to claim 27:

> wherein the combustion chamber comprises ~~the~~ added Br2, HBr, Br-, ~~the bromide compound~~, or a combination thereof."

Claim 20 is disclosed because exemplary bromine-containing ingredients added to the combustion chamber are aqueous hydrogen bromide [HBr(aq)], molecular bromine (Br_2), alkali bromides (such as sodium bromide [NaBr(aq)], and mixtures thereof). The bromine (Br_2), HBr, sodium bromide, and other bromide compounds are added to "coal or the like to be burnt, upstream of the furnace" and are also added "into one or both combustion chambers."[1172] Vosteen also discloses adding a bromide ion (Br^-) to the combustion chamber, in that a POSITA would understand that the aqueous solutions of hydrogen bromide and sodium bromide each dissociate in water (and in the furnace) to form bromide ions.[1173]

XXV. GROUND G: OBVIOUSNESS OF THE '225 PATENT OVER SJOSTROM AND ECKBERG

812. It is my opinion that Sjostrom either alone or in combination with the background knowledge of a POSITA or Eckberg renders obvious each of asserted claim of the '225 patent.

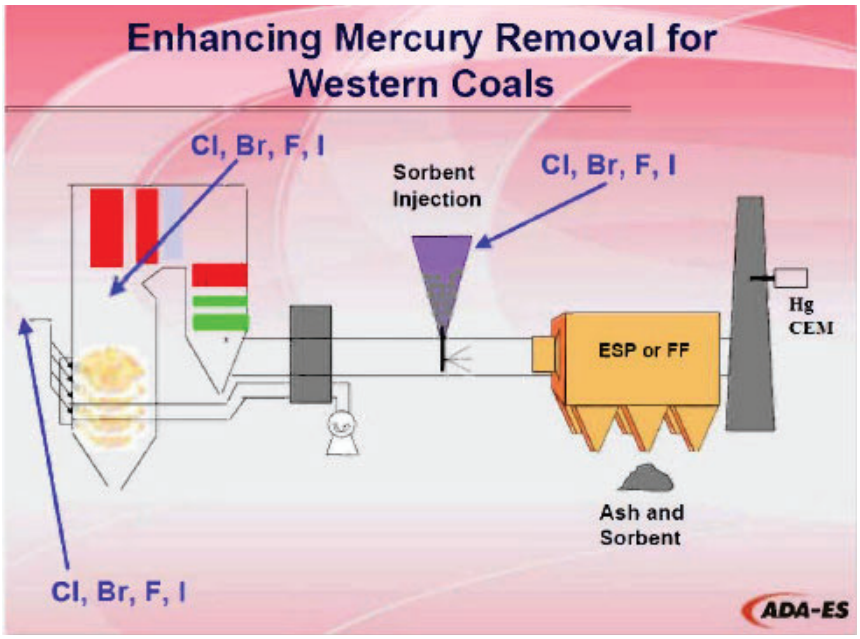
[1172] Ex. 1008 (Vosteen) at 4:4-19; see Claim 1 ("bromine . . . is fed to the furnace"; "applying . . . bromine compounds to a coal").

[1173] Ex. 1008 (Vosteen) at 2:58-61, 4:4-19, 4:27-33.

A. INDEPENDENT CLAIM 1

1. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising: "

813. The preamble is disclosed by Sjostrom. Sjostrom teaches treating a mercury-containing gas. The title of Sjostrom is "Full Scale Evaluations of ***Mercury Control Technologies*** with PRB Coals."[1174] Specifically, Sjostrom described various mercury control tests conducted at coal-fired power plants.[1175] Sjostrom described testing mercury removal from the mercury-containing flue gas of coal-fired power plants involving sorbent injection and halogen addition, as detailed below.[1176]



Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)" achieved throughout the testing performed on coal flue

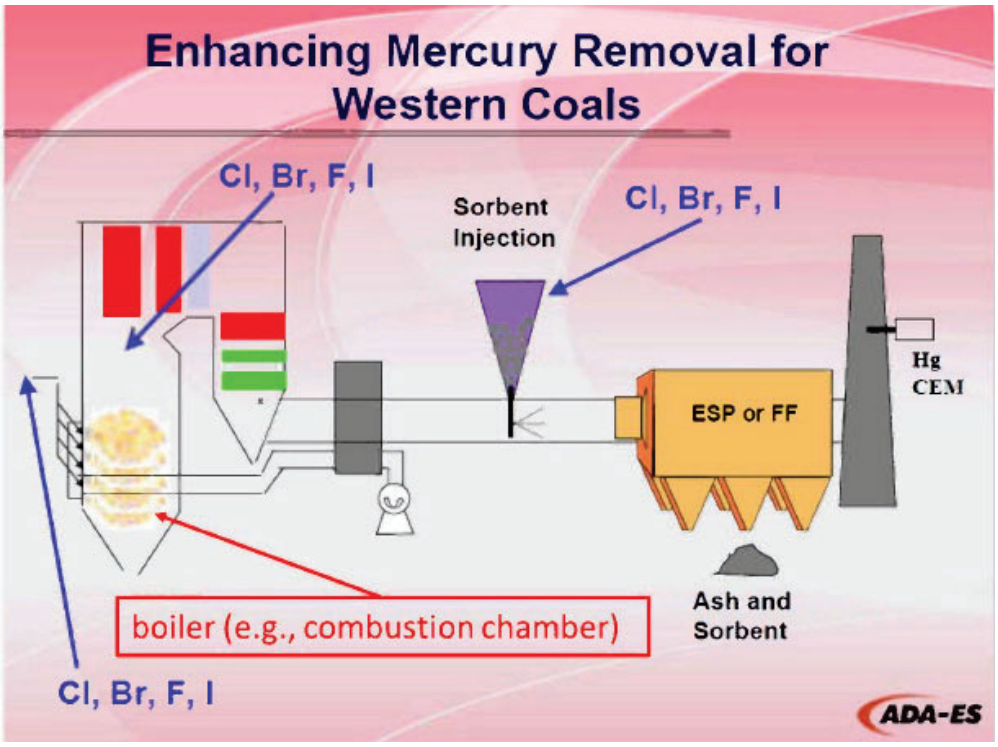
1174 Ex. 1010 (Sjostrom) at 1 (emphasis added).
1175 Ex. 1010 (Sjostrom) at 12, 18.
1176 Ex. 1010 (Sjostrom) at 4.

gas.[1177] This annotated figure in Sjostrom specifically shows that particulate matter, including the mercury-sorbent composition, would have been separated from the flue gas by the ESP or FF, because a POSITA would have understood that it was well-known to use an ESP or FF to remove such solid materials.[1178]

2. Claim 1: Element (1)(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

814. This limitation is disclosed by Sjostrom. This limitation is also obvious over Sjostrom in view of Eckberg. As discussed above, Sjostrom described various mercury control tests conducted at coal-fired power plants.[1179] These plants combust coal in a coal-fired boiler (e.g., combustion chamber) as shown in the annotated figure below.[1180]

[1177] Ex. 1010 (Sjostrom) at 8, 15-17, 20, and 21.
[1178] State of the Art, § XII.B.5.a
[1179] Ex. 1010 (Sjostrom) at 12, 18.
[1180] Ex. 1010 (Sjostrom) at 4 (annotations in red).

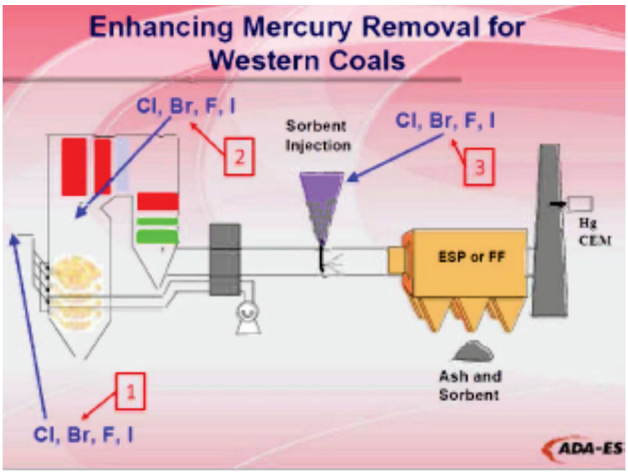


A POSITA would have understood that this unit was a boiler based on the image used to represent the unit in the drawing, which was a common and routine way to represent a coal-combustion chamber (boiler). Sjostrom explains that at the time of testing, both of the coal-fired power plants tested combusted PRB (Powder River Basin) coal having a mercury content of "0.04 — 0.1 ppm-dry.[1181] Relying only on existing equipment at these plants, Sjostrom shows that the outlet mercury content of the flue gas was 11.2 µg/dncm.[1182] Thus, Sjostrom discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury-containing gas.

1181 Ex. 1010 (Sjostrom) at 12, 18.

1182 Ex. 1010 (Sjostrom) at 3.

815. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving halogen injection.[1183] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal power process."[1184]



Addition Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[1185] Addition Location 2 of Sjostrom discloses injecting bromine into the boiler.[1186] Location 3 of Sjostrom discloses adding bromine to the mercury containing gas through the injection of PAC sorbent into the flue gas.[1187]

816. A POSITA would have found it obvious that the "Br" of Sjostrom would be a widely available bromine-containing material, such as HBr or an aqueous

1183 Ex. 1010 (Sjostrom) at 4.
1184 Ex. 1010 (Sjostrom) at 4 (annotations in red).
1185 Ex. 1010 (Sjostrom) at 4 (annotations in red).
1186 Ex. 1010 (Sjostrom) at 4 (annotations in red).
1187 Ex. 1010 (Sjostrom) at 4 (annotations in red).

solution of a bromide compound, such as CaBr2, for Addition Location 1 and Addition Location 2. Further, Sjostrom teaches the addition of "KNX (Alstom Power)."[1188] KNX was a known aqueous solution of a bromide salt additive developed for enhanced mercury control. As discussed above, Addition Location 1 of Sjostrom renders obvious adding bromine-containing species upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[1189] Thus, Sjostrom renders obvious the mixture being combusted comprises coal and an additive comprising HBr, a bromide compound, or a combination thereof.

817. Furthermore, a person of skill in the art would have looked to the Eckberg reference to further tune implementation of a system like that of Sjostrom because it would have identified well-known chemical substances that could be used as the "Cl" or "Br" identified in the figures of Sjostrom. (adding calcium bromide, $CaBr_2$, onto the coal or into the combustion chamber and having it react to provide HBr in the flue gas), as well as the flow rate of calcium bromide, the resulting bromine:coal ratio, and the resulting concentration of HBr in the flue gas in such a system. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" or "$CaBr_2$ (52 wt%)" into the combustion chamber.[1190] As a result of this injection, the bromine is

[1188] Ex. 1010 (Sjostrom) at 23.
[1189] Ex. 1010 (Sjostrom) at 4 (annotations in red).
[1190] Ex. 1011 (Eckberg) at 9.

provided at a 0.09 weight % (relative to coal), which dissociates and further reacts in the gas phase to provide 50 ppm HBr in the flue gas.[1191]

818. Like Sjostrom, Eckberg also teaches enhancing mercury removal through halogen injection into a boiler. Eckberg describes several testing objectives including "[i]ncreas[ing] mercury oxidation in flue gas derived from Texas lignite" and "[e]nhanc[ing] mercury removal across wet scrubbers." Eckberg also describes testing the mercury removal effects of halogen injection directly into a coal-fired boiler.[1192]

819. Eckberg described a similar location as Sjostrom for adding halogens into the overall system, namely directly within the boiler. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen addition, and a combination of the two. Specifically, the annotated figure below shows that Sjostrom teaches adding halogens in at least three locations.

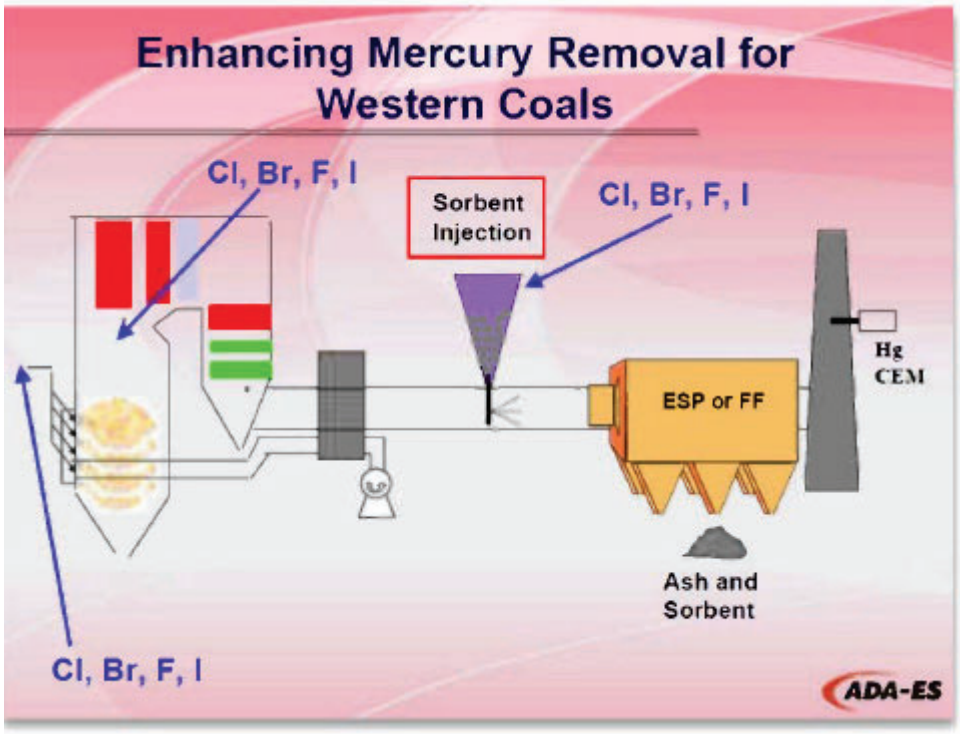
820. I understand that under the Plaintiffs' theory of infringement in this case, and consistent with the Court's claim construction ruling, combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof does not require the addition of pyrolysis char to system. I understand that under this theory this claim element of pyrolysis char as

[1191] Ex. 1011 (Eckberg) at 9.
[1192] Ex. 1011 (Eckberg) at 5.

it appears in Claim 1 is met if the combustion of coal produces some pyrolysis char, even briefly. I agree with Defendants that some pyrolysis char inevitably will be formed whenever coal is being combusted, including in the combustion systems disclosed in Sjostrom in Eckberg.

3. Claim 1: Element (1)(c)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

821. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[1193]



[1193] Ex. 1010 (Sjostrom) at 4 (annotations in red).

As shown in the above figure, the "Sorbent Injection" occurs downstream from a combustion chamber. Specifically, Sjostrom described testing performed with activated carbon injection, including injection of "DARCO FGD."[1194] A POSITA would have understood that DARCO FGD was a well-known type of activated carbon used for mercury capture.[1195]

B. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char

822. As described for Claim 1, the char present in the combustion mixture is the char present from the combusting of coal. As described for Claim 1, the Sjostrom reference also discloses the addition of bromine compounds into the combustion zone. According to Defendants' own theories of infringement, the formation of char during the combustion of coal in the presence of bromine will lead to the formation of some promoted pyrolysis char.

2. Claim 5: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

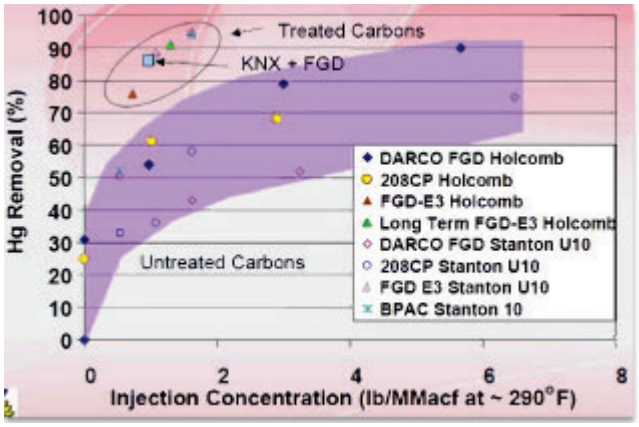
823. This limitation is disclosed by Sjostrom. Sjostrom includes numerous charts showing greater than 70 % removal of mercury from the flue gas. For example,

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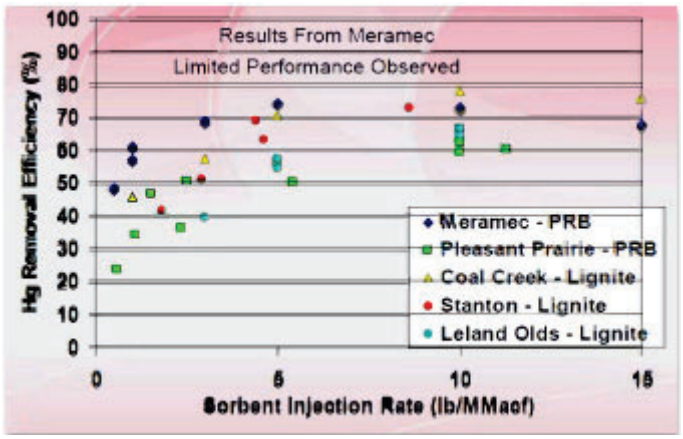
[1194] Ex. 1010 (Sjostrom) at 10, 11, 16.

[1195] See, e.g., State of the Art, Sections XII.C.3, XII.G.2.

the below chart shows the mercury removal from testing at a plant using the system of Sjostrom.[1196]



Similarly, the below chart shows the mercury removal from testing at a plant using the system of Sjostrom.[1197]

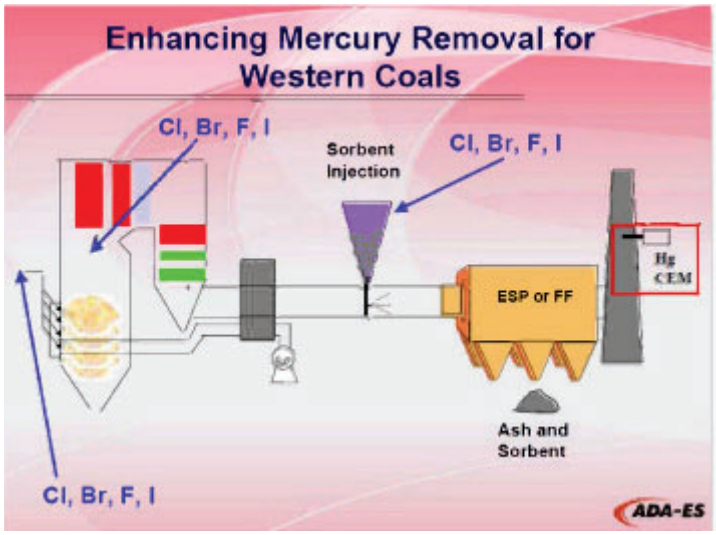


3. Claim 6: Element (6)(a)—"The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and "

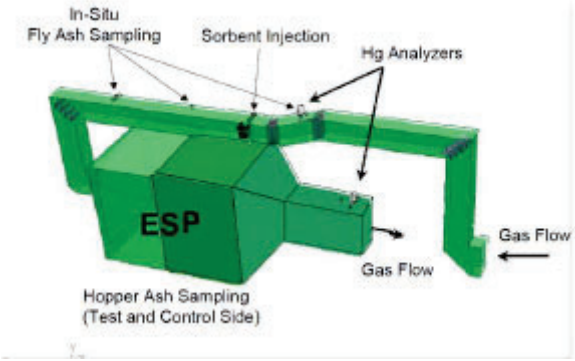
1196 Ex. 1010 (Sjostrom) at 16.

1197 Ex. 1010 (Sjostrom) at 20.

824. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom describes passing the treated flue gas through a stack with an attached Hg CEM (continuous emissions monitor) attached.[1198]

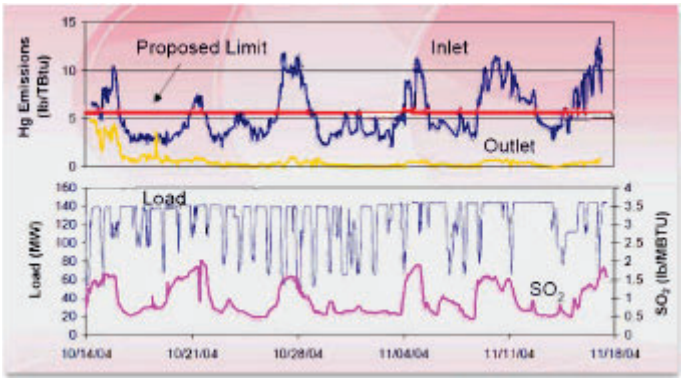


Further, Sjostrom discusses taking Hg measurements at both the inlet and outlet of the ESP as shown below.[1199]

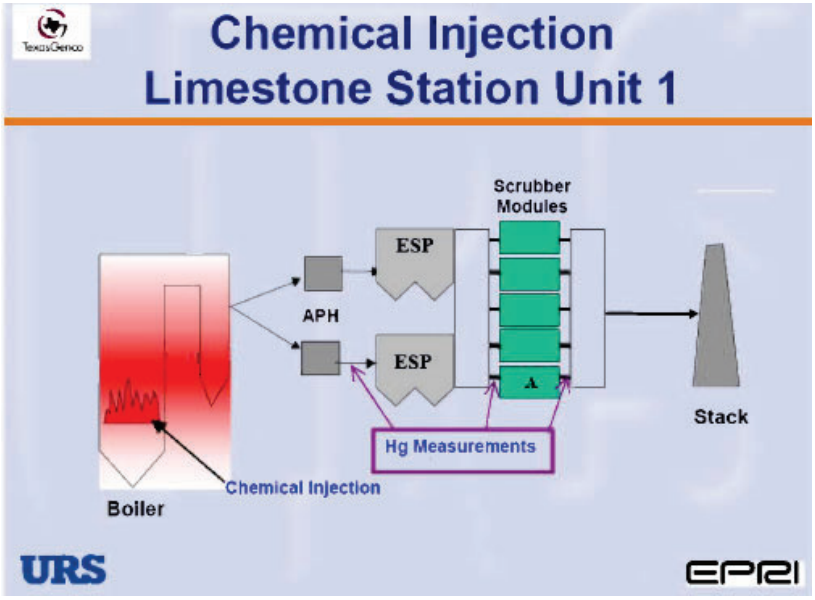


1198 Ex. 1010 (Sjostrom) at 4 (annotations in red).
1199 Ex. 1010 (Sjostrom) at 19.

Sjostrom includes the chart showing the Hg emissions as measured at the inlet and outlet of the ESP[1200]



825. As shown in the figure below, and similar to Sjostrom, Eckberg also describes testing the mercury removal effects of halogen injection directly into a coal-fired boiler.[1201]



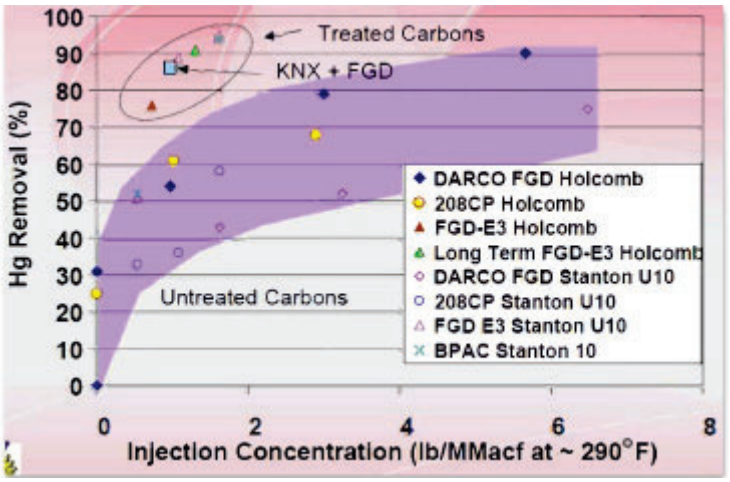
4. Claim 6: Element 6(b)

[1200] Ex. 1010 (Sjostrom) at 22.

[1201] Ex. 1011 (Eckberg) at 5.

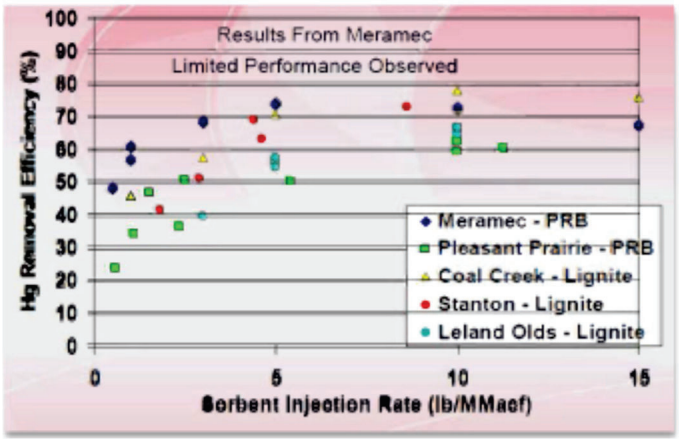
a. **<u>Element (6b)</u>—"modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."**

826. This limitation is disclosed by Sjostrom. Sjostrom includes numerous charts of measured mercury removals for various injection rates of activated-carbon sorbents. For example, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[1202]



Similarly, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[1203]

[1202] Ex. 1010 (Sjostrom) at 16.
[1203] Ex. 1010 (Sjostrom) at 20.

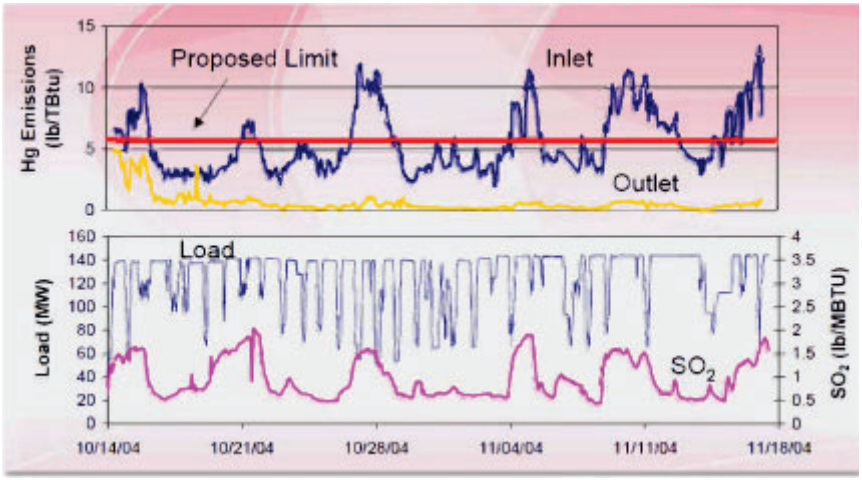


827. The fact that there is a graph that has datapoints for different sorbent injection rates (the independent variable) and associated Hg removal percentages (the dependent variable) means that a POSITA would have understood that there is a relationship between the Hg removal % and the sorbent injection rate. Given that, and a target Hg removal rate, a POSITA would have understood that the sorbent injection rate would be adjusted to result in a target removal %.

828. As discussed previously, a POSITA would have known that activated carbon was expensive, especially relative to costs of components such as "Br" in the form of HBr or an aqueous bromide salt solution. Thus, a POSITA would have been motivated to maintain the sorbent injection rate at the minimum level necessary to reach the desired level of mercury emissions. A POSITA viewing the charts of Sjostrom showing mercury removal versus sorbent injection rate would have been motivated to use the charts to control the sorbent injection rate at a level that minimized costs while reaching mercury removal targets. Thus, Sjostrom discloses modifying, in response to the measured mercury content, an injection rate of the

sorbent into the mercury-containing gas, the amount of additive in the mixture [I believe it is Nelson that shows the same plot for different amounts of Br on the PAC sorbent, if you want a clear demonstration], or a combination thereof.

829. The below figure from Sjostrom shows that the testing focused on a "Proposed Limit.[1204]



Thus, Sjostrom teaches maintaining the mercury content of the cleaned gas "at or below a desired level" (e.g., the 'Proposed Limit."). A POSITA would have been motivated to control the activated carbon injection rate to reach this desired level while minimizing the amount of activated carbon injected. A POSITA would have understood that injecting too much activated carbon would have increased the costs of the mercury removal process and injecting too little activated carbon may lead to mercury emissions rising above actionable levels.

[1204] Ex. 1010 (Sjostrom) at 22.

830. Eckberg also suggest further testing to balance the amount of additive injection to limit effects such as boiler corrosion and air heater plugging.[1205]

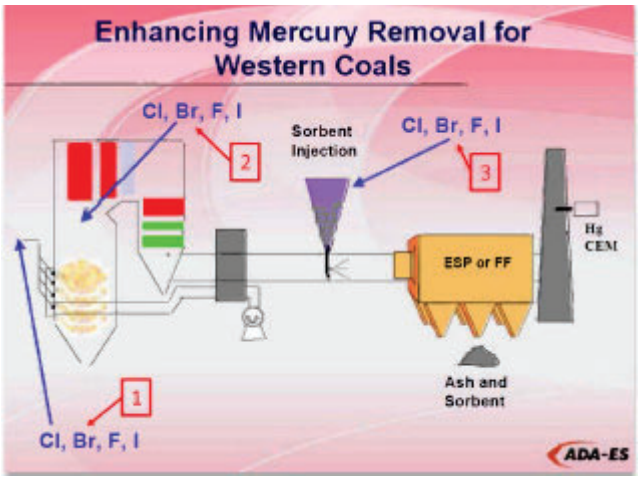
5. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

831. This limitation is disclosed by Sjostrom. Sjostrom described that its activated carbon includes PAC ("powdered activated carbon") sorbents, including Darco FGD, a known powdered activated carbon sorbent.[1206]

6. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

832. This limitation is disclosed by Sjostrom. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[1207] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal power process.[1208]

[1205] Ex. 1011 (Eckberg) at 16.
[1206] Ex. 1010 (Sjostrom) at 15-16, 20-21.
[1207] Ex. 1010 (Sjostrom) at 4
[1208] Ex. 1010 (Sjostrom) at 4 (annotations in red).



833. Addition Location 1 of Sjostrom renders obvious injecting bromine or other halogens upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[1209] Addition Location 2 of Sjostrom teaches injecting bromine or other halogens into the boiler.[1210] Addition Location 3 of Sjostrom teaches adding bromine or other halogens to the mercury sorbent that is injected into the flue gas.[1211] Thus, Sjostrom teaches injecting bromine or other halogens in one or more of the three above injection locations. Specifically, Sjostrom teaches that bromine may be injected at either Addition Location 1 or Addition Location 2 while another halogen (e.g., Cl or I) may be injected at Addition Location 3 with the sorbent material.[1212] A POSITA would understand the obvious forms of halogen to be used for the injection at those locations are the commonly used (readily available and safe) halogen salts

1209 Ex. 1010 (Sjostrom) at 4 (annotations in red).
1210 Ex. 1010 (Sjostrom) at 4 (annotations in red).
1211 Ex. 1010 (Sjostrom) at 4 (annotations in red).
1212 Ex. 1010 (Sjostrom) at 4.

with alkali metals and alkaline earth metals, such as NaCl, KCl, $CaCl_2$, $MgBr_2$, $CaBr_2$, and $MgBr_2$.

834. To the extent Sjostrom does not disclose this limitation, it is obvious over Sjostrom in view of Eckberg. For example, to the extent Sjostrom does not disclose a specific chemical compound or concentration to use as the injected "alkaline" secondary material, Eckberg provides these details. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%), which is an alkaline earth salt.[1213] A POSITA would have been motivated to apply the teachings of Eckberg regarding chlorine injection to the system of Sjostrom regarding halogen injection, for the same reasons described in the "Reasons to Combine" section, regarding applying Eckberg's teachings regarding bromine composition injection.

7. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

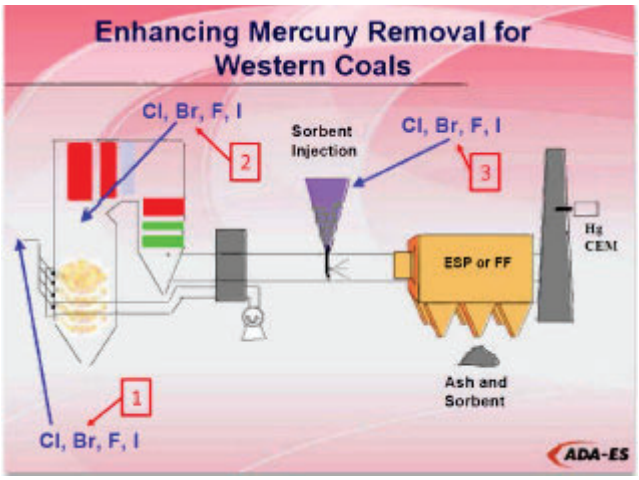
835. The language of claim element 18 is substantially identical to the language of claim 6. Accordingly, the explanation I provide above for claim elements 6(a) and 6(b) applies equally to claim element 18.

8. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal

[1213] Ex. 1011 (Eckberg) at 9.

enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility"

836. This limitation is disclosed by Sjostrom and would otherwise be obvious based on the background knowledge of a POSITA. Specifically, the annotated figure below shows that Sjostrom renders obvious injecting bromine or other halogens upstream of the combustion chamber, such as by adding it to the coal entering the boiler, at Addition Location 1, by injecting halogens directly into the manifold that carries coal and primary air into the burners.[1214]



A POSITA would understand based on his or her background knowledge in the art that the addition could be performed at the coal-combustion facility in order to limit transport costs.

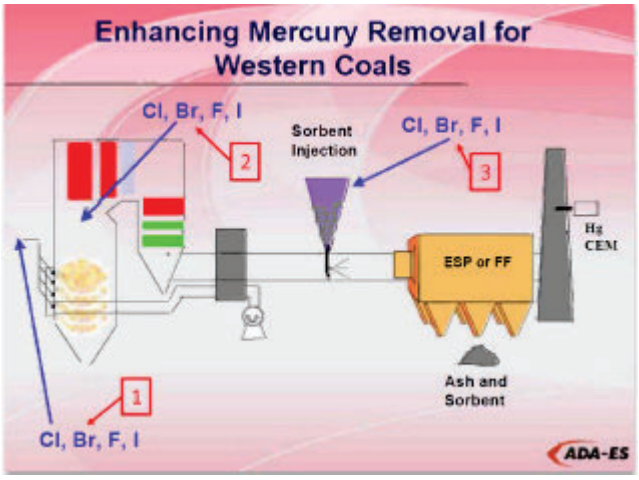
9. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

[1214] Ex. 1010 (Sjostrom) at 4 (annotations in red).

837. This limitation is disclosed by Sjostrom. Sjostrom described using coal that included subbituminous coal.[1215]

10. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

838. This limitation is disclosed by Sjostrom. The system described by Sjostrom, which represents a coal combustion facility, includes "Sorbent Injection" upstream of the "ESP or FF", which signifies to a POSITA an electrostatic precipitator or fabric filter.[1216] Electrostatic precipitators and fabric filters are examples of particulate control systems.



1215 Ex. 1010 (Sjostrom) at 3.

1216 Ex. 1010 (Sjostrom) at 4 (annotations in red).

C. INDEPENDENT CLAIM 14

1. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:

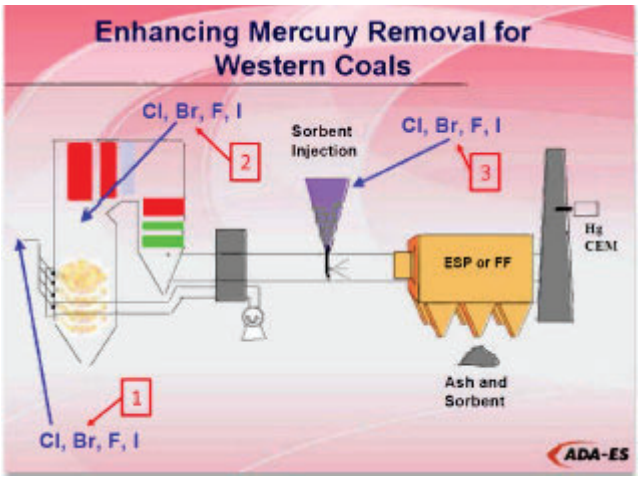
839. The language of the preamble of claim 14 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 14.

2. Claim 14: Element (14a)—"combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas"

840. The language of claim element 14(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 14(a).

841. To the extent that Element 14(a) additionally requires the combusting step be in a combustor, Sjostrom discloses this element. Sjostrom discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing flue gas stream. Addition Location 2 shows addition of a halogen additive into the combustor.[1217]

[1217] Ex. 1010 (Sjostrom) at 4 (annotations in red).



3. Claim 14: Element (14b)—"and adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

842. The language of claim element 14(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 14(b).

D. CLAIMS DEPENDING FROM CLAIM 14

1. Claim 15: The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char

The language of claim 15 is substantially identical to the language of claim 2. Accordingly, the explanation I provide above for claim 2 applies equally to claim 15.

E. INDEPENDENT CLAIM 17

1. Claim 17: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

843. The language of the preamble of claim 17 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 17.

2. Claim 17: Element (17a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and "

844. The language of claim element 17(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 17(a).

3. Claim 17: Element (17b)—"adding a sorbent material comprising activated carbon into the mercury-containing gas"

845. The language of claim element 17(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 17(b).

XXVI. GROUND H: ANTICIPATION OF THE '225 PATENT OVER DOWNS-BOILER

846. It is my opinion that Downs-Boiler anticipates, or in combination with the background knowledge of a POSITA renders obvious, each of asserted claim of the '225 Patent.

A. INDEPENDENT CLAIM 1

1. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising: "

847. Downs-Boiler discloses the preamble. The title of Downs-Boiler is "Bromine Addition for the Improved Removal of Mercury from Flue Gas.[1218] Flue gas is an example of a mercury-containing gas, and "removal of mercury" refers to separating the mercury from a mercury-containing gas. Downs-Boiler repeatedly characterizes the disclosed process as for removing *(i.e.,* separating) mercury from flue gas (i.e., a mercury-containing gas):

> [T]he use of bromine-containing compounds, added to the coal, or to the boiler combustion furnace, are significantly more effective than chlorine-containing compounds in enhancing the oxidation of mercury, thereby enhancing the overall removal of mercury in downstream pollution control devices.[1219]

Claim 1 of Downs-Boiler also recites a similar preamble: "1. A method of removing a portion of the elemental mercury in a flue gas"[1220] The removal of mercury from the flue gas as described by Downs-Boiler is by separating the mercury along with a sorbent:[1221]

> The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often

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[1218] Ex. 1006 (Downs-Boiler) at Title; Ex. 1007 (Downs-Boiler-Provisional) at Title

[1219] pg completed formatting/need to do QCEx. 1006 (Downs-Boiler) ¶ [0007]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [0013].

[1220] Ex. 1006 (Downs-Boiler) at Claim 1; see also Ex. 1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising.").

[1221] Ex. 1006 (Downs-Boiler) ¶ [0004] (emphasis added); Ex. 1007 (Downs-Boiler-Provisional) IT [005].

been successfully applied for the *separation and removal* of trace quantities of undesirable components.

Downs-Boiler characterizes its disclosed "invention" as "a cost-effective method of removing elemental mercury from coal combustion flue gases."[1222]

2. Claim 1: Element (1)(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

848. Downs-Boiler discloses this claim element. Downs-Boiler discloses HBr or a bromide compound, or a combination thereof, as its bromine-containing reagent that is added to the coal upstream of the combustion chamber. Downs-Boiler explains that its bromine-containing reagent may comprise, "but is not limited to, *alkali metal* and *alkaline earth metal bromides, hydrogen bromide (HBr)* or *bromine (Br_2).*"[1223] Downs-Boiler also specifically discloses *calcium bromide ($CaBr_2$)* as another bromide compound suitable for use as the bromine-containing reagent.[1224]

849. The bromine-containing reagent is applied to the coal upstream of the combustion chamber and thus the coal and reagent would be part of the mixture being combusted. Downs-Boiler teaches that a "bromine containing reagent 10 is added to

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[1222] Ex. 1006 (Downs-Boiler) ¶ [0018]; Ex. 1007 (Downs-Boiler-Provisional) ¶ [021].

[1223] Ex. 1006 (Downs-Boiler) 41] [0021] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) 'll [0024].

[1224] Ex. 1006 (Downs-Boiler) 11 [0018-19] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) l] [0021-22].

the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16."[1225] According to the preferred embodiment of Downs-Boiler, ***"an aqueous solution*** of calcium bromide is sprayed ***onto the crushed coal 16*** before the coal 16 is pulverized for combustion. The aqueous solution is easily handled and metered *onto the coal 16*" such that the *"coal pulverizers 28 intimately mix the bromide reagent 10 with the coal 16,* and the pulverized coal conveying system 30 to the several coal burners (not shown) ensures an even distribution of the reagent 10 across the boiler furnace 14."[1226] Thus, upstream of the combustion chamber, such as in the coal pulverizers and the pulverized coal conveying system, at least one or a combination of HBr and a bromide compound (e.g., calcium bromide ($CaBr_2$)) has been added on the coal.

850. Downs-Boiler also discloses "the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof." As described above—where the bromine-containing reagent is disclosed as added to the coal and/or the coal conveying system—this further discloses that the mixture being combusted comprises coal and the added bromine-containing reagent *(e.g.,* Br_2, HBr, a bromide compound, or a combination thereof). As explained by Downs-Boiler, as a result of

[1225] Ex. 1006 (Downs-Boiler) 11 [0015]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0018].

[1226] Ex. 1006 (Downs-Boiler) ¶ [0019], Figure 2; *see also* Ex. 1007 (Downs-Boiler-Provisional) III [0022], Figure 2.

adding the bromine-containing reagent to the coal and/or the coal conveying system, the "***[b]romine species released during the combustion process*** enhance the oxidation of mercury as the combustion gases pass ***through the furnace 14***."[1227] That the bromine-containing reagent is "sprayed on the crushed coal 16 before the coal is pulverized for *combustion"* additionally "ensures even distribution of the [bromine-containing] reagent 10 ***across the boiler furnace"*** *(i.e.,* in the combustion chamber).[1228]

851. Downs-Boiler also discloses introduction of HBr, and/or a bromide compound *(i.e.,* the bromine-containing reagent) directly into the combustion chamber. Downs-Boiler teaches that a "bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16"[1229]. Downs-Boiler describes that the inventors successfully tested direct introduction of the bromine-containing reagent—specifically, a bromide compound of calcium bromide ($CaBr_2$)—"injected into the combustion chamber 14 through a coal burner."[1230] Downs-Boiler further recognizes that "the bromine-

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[1227] Ex. 1006 (Downs-Boiler) 11 [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018].

[1228] Ex. 1006 (Downs-Boiler) ¶ [0019] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0022].

[1229] Ex. 1006 (Downs-Boiler) ¶ [0015]; see also Ex. 1007 (Downs-Boiler-Provisional) 11 [0018].

[1230] Ex. 1006 (Downs-Boiler) 11 [0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0021].

containing reagent 10 may be fed to the boiler combustion zone 14 in gaseous, liquid, or solid form."[1231] Thus, the mixture that is being combusted comprises at least one or a combination of HBr and a bromide compound *(e.g.,* calcium bromide ($CaBr_2$)).

852. Third, Downs-Boiler discloses adding a bromine-containing reagent to both the coal and the combustion chamber. As described above, Downs-Boiler describes applying the bromine-containing reagent to the coal upstream of the combustion chamber in such a way that added HBr and/or a bromide compound *(e.g.,* calcium bromide ($CaBr_2$)) is both on the coal *and* in the combustion chamber.

853. Furthermore, as illustrated in Figure 2, reproduced below as annotated, Downs-Boiler illustrates that the bromine-containing reagent may be introduced "to addition points A, B, C" including "coal preparation," "the pulverized coal conveying system 30," and "the boiler furnace 14."[1232]

[1231] Ex. 1006 (Downs-Boiler) ¶ [0022]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0025].

[1232] Ex. 1006 (Downs-Boiler) ¶ [0019], Figure 2 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0022], Figure 2.

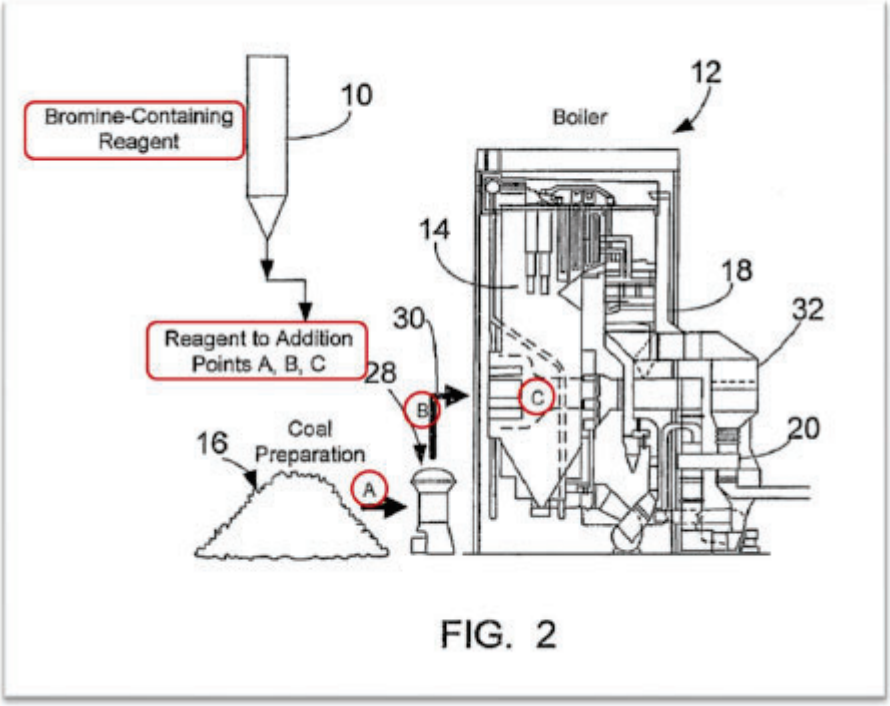


FIG. 2

854. Downs-Boiler in no way restricts simultaneous introduction to each of points A, B, and C. Rather, as described above, Downs-Boiler invites, if not encourages, simultaneous introduction to each of points A, B, and C or some combination of A/B and C to "intimately mix the bromide reagent 10 with the coal" so as to achieve a more "even distribution of the reagent 10 across the boiler furnace 14."[1233]

855. I understand that under the Plaintiffs' theory of infringement in this case, and consistent with the Court's claim construction ruling, combusting a mixture of comprising coal, pyrolysis char, and an additive comprising HBr, a bromide

[1233] Ex. 1006 (Downs-Boiler) ¶ [0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0022].

compound, or a combination thereof does not require the separate addition of pyrolysis char to system. I understand that under this theory this claim element of pyrolysis char as it appears in Claim 1 is met if the combustion of coal produces some pyrolysis char, even briefly. I agree with Defendants that some pyrolysis char will be formed whenever coal is being combusted, including in the combustion systems disclosed in Downs-Boiler. Accordingly, the combusting of coal with added bromine reagent disclosed in Downs-Boiler is the combusting of coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas.

3. Claim 1: Element (1)(c)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

856. Downs-Boiler discloses adding a particulate sorbent material comprising activated carbon, referring to the example of "powdered activated carbon (PAC)."[1234] Powdered activated carbon is activated carbon in particulate form. Downs-Boiler explains that the use of a conventional PAC injection process is improved by the addition of bromine, in that the bromine-containing reagent "enhances the removal of mercury across a ***PAC injection*** process."[1235] Downs-Boiler

[1234] Ex. 1006 (Downs-Boiler) ¶ [0025]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0028].

[1235] Ex. 1006 (Downs-Boiler) ¶ [0016] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0019].

repeats in other places that the bromine-containing reagent saves costs by making more efficient use of the activated-carbon sorbent material that is "inject[ed]."[1236] As explained by Downs-Boiler, the disclosed injected activated-carbon sorbent materials (e.g., sorbent injection systems using PAC) are part of *"downstream* pollution control systems such as . . . PAC injection systems."[1237] Here, "downstream" is relative to the location of the combustion chamber, and thus after generation of the mercury-containing gas. The activated-carbon sorbent material is injected into a mercury-containing gas: "injection of a carbonaceous *sorbent* (e.g., powdered *activated carbon,* or PAC) *into the flue gas* upstream of the dust collector to *adsorb vapor-phase mercury.*"[1238]

B. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char

857. As described for Claim 1, the char present in the combustion mixture is the char present from the combusting of coal. As described for Claim 1, the Downs-

[1236] Ex. 1006 (Downs-Boiler) ¶ [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0018].

[1237] Ex. 1006 (Downs-Boiler) ¶ [0004]; see also Ex. 1007 (Downs-Boiler-Provisional)¶ [005].

[1238] Ex. 1006 (Downs-Boiler) ¶¶ [0004], [0015], [0016], and [0025]; *see also* Ex. 1007 (Downs-Boiler-Provisional) in [005], [0018], [0019], and [0028].

Boiler system includes the addition of the claimed bromine species into the combustion zone. According to Defendants' own theories of infringement, the formation of char during the combustion of coal in the presence of bromine will lead to the formation of some promoted pyrolysis char.

2. Claim 5: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

858. This limitation is disclosed by Downs-Boiler. According to Figure 3, reproduced below as annotated, Downs-Boiler indicates that the disclosed method for removing mercury from the flue gas resulted in mercury emissions at the outlet of the fabric filter of approximately 2 μg/dscm (blue) as compared to an initial value *(i.e.,* the mercury inventory of the system) at the inlet of the fabric filter of approximately 9 μg/dscm (red).[1239]

[1239] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

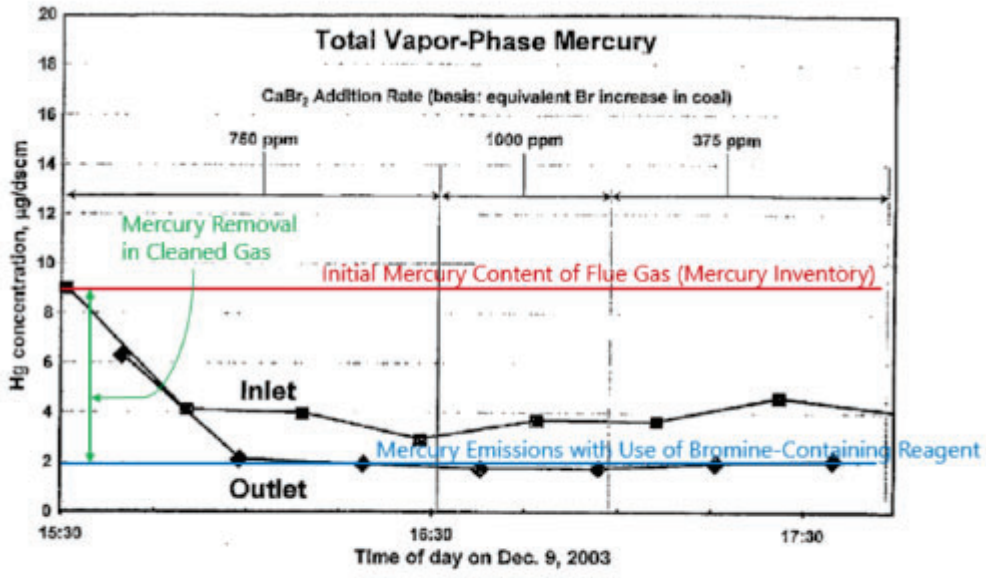


FIG. 3

Therefore, the use of the method disclosed by Downs-Boiler in conjunction with a fabric filter resulted in a system mercury removal of approximately 7 µg/dscm (green). This removal of the mercury in the mercury containing gas (7 µ g/dscm) as compared to the mercury inventory of the system (9 µg/dscm) may also be expressed as a percentage: at least 77 wt% of the mercury in the mercury-containing gas was removed—or in other words: removing greater than 70 wt% of the mercury in the mercury-containing gas.

859. Furthermore, as described in my background section,[1240] a POSITA would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations requiring 70% mercury removal, including the EPA's

[1240] State of the Art, XII.D — XII.F.

Clean Air Mercury Rule (CAMR). Downs-Boiler further teaches compliance with EPA standards regulating mercury emissions from coal-fired plants.[1241] Notice of these regulations exerted a strong outside impetus on the industry to adjust processes to comply with the regulations' eventual implementation. Through routine process optimization and routine experimentation, a POSITA would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

3. Claim 6: Element (6)(a)—"The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and "

860. This limitation is disclosed by Downs-Boiler. The mercury content is monitored, as depicted by the Y-axis of Figure 3 *(i.e.,* the "Hg concentration" in µg/dscm).[1242] The units "µg/dscm" refer to micrograms of mercury per standard cubic meter of flue gas on a dry basis.

[1241] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [002].

[1242] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

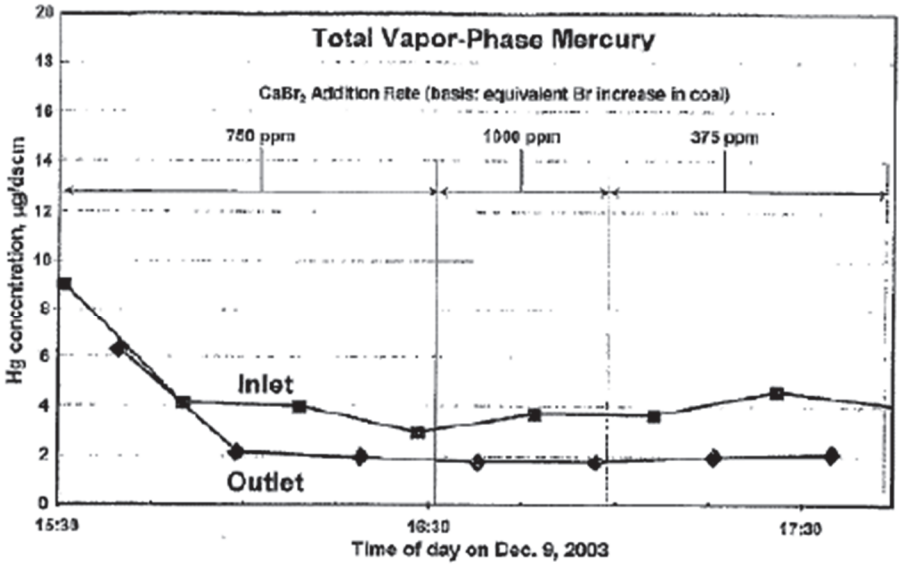


FIG. 3

In particular, Figure 3 shows that the mercury content of the cleaned gas (the data set provided by diamond markers for the outlet of the particulate collector) is monitored for a period of over two hours.[1243]

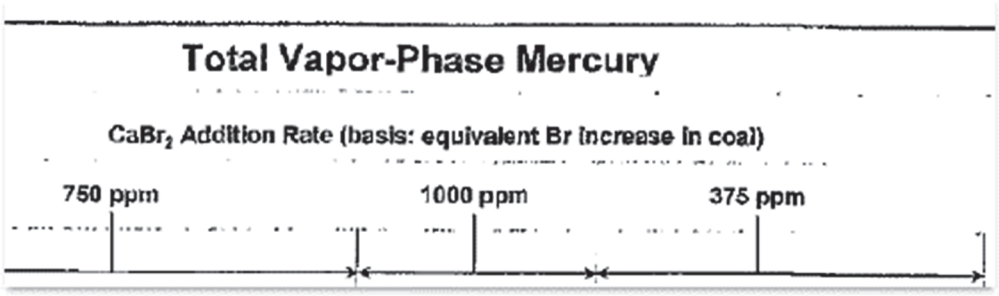
4. Claim 6: Element 6(b)

a. Element (6b)—"modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

861. This limitation is obvious over Downs-Boiler. As illustrated by Figure 3 of Downs-Boiler, excerpted below, in response to continuously monitoring the mercury content of the cleaned gas, the amount of additive (in this case the bromide

[1243] Ex. 1006 (Downs-Boiler) Figure 3; *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

compound $CaBr_2$) added into the mixture for combustion was continuously adjusted between a range of 375 to 1000 parts per million of a bromine-containing reagent



($CaBr_2$).[1244] By adjusting the amount of bromine-containing reagent applied, it would have been understood by a POSITA that this would modify the amount of additive in the mixture. A POSITA reviewing the monitored data as presented by Figure 3 of Downs-Boiler would have understood that the monitored mercury content at the outlet of the particulate collector could be used to modify the addition rate of the bromine-containing reagent thereby controlling the amount of the additive in the mixture.

862. It would have also been obvious to control the sorbent injection rate. As described above, Downs-Boiler discloses that the injection of sorbents was effective for the removal of mercury but as the rate of injecting the sorbent into the mercury-containing gas increases, the "economics of high injection rates can be prohibitive"

[1244] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

due to the costs of the consumable sorbent material.[1245] The normal desire of a POSITA to improve on a given process would have been to adjust the result-effective variable of the injection rate of the sorbent so as not to wastefully inject excessive sorbent once sufficient mercury removal was demonstrated, in order to minimize costs associated with operating the sorbent injection system. Furthermore, due to the variability of the composition of coal as a fuel source (including for example, native mercury and halogen content), as described in the State of the Art,[1246] it would have been obvious that some amount of adjustment to the rate of injection of the sorbent into the flue gas would be performed as part of routine process control and optimization to account for variances in the coal.

5. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

863. This limitation is disclosed by Downs-Boiler. Downs-Boiler discloses the use of a "sorbent injection system" for the purpose of injecting a "carbonaceous sorbent" including at least "powdered activated carbon (PAC), carbons and chars

[1245] Ex. 1006 (Downs-Boiler) ¶ [0004]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [005].

[1246] State of the Art, § XII.B.1.

produced from coal and other organic materials, and unburned carbon produced by the combustion process itself."[1247]

6. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

864. This limitation is disclosed by Downs-Boiler. As discussed for Claim 1 above, Downs-Boiler explains that its bromine-containing reagent may comprise, "but is not limited to, *alkali metal* and *alkaline earth metal bromides, hydrogen bromide (HBr)* or *bromine (Br_2).*"[1248] Furthermore, as illustrated in Figure 2, reproduced below as annotated, Downs-Boiler illustrates that the bromine-containing reagent may be introduced "to addition points A, B, C" including "coal preparation," "the pulverized coal conveying system 30," and "the boiler furnace 14."[1249]

[1247] Ex. 1006 (Downs-Boiler) ¶ [0025]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0028].

[1248] Ex. 1006 (Downs-Boiler) 41] [0021] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) 'll [0024].

[1249] Ex. 1006 (Downs-Boiler) ¶ [0019], Figure 2 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0022], Figure 2.

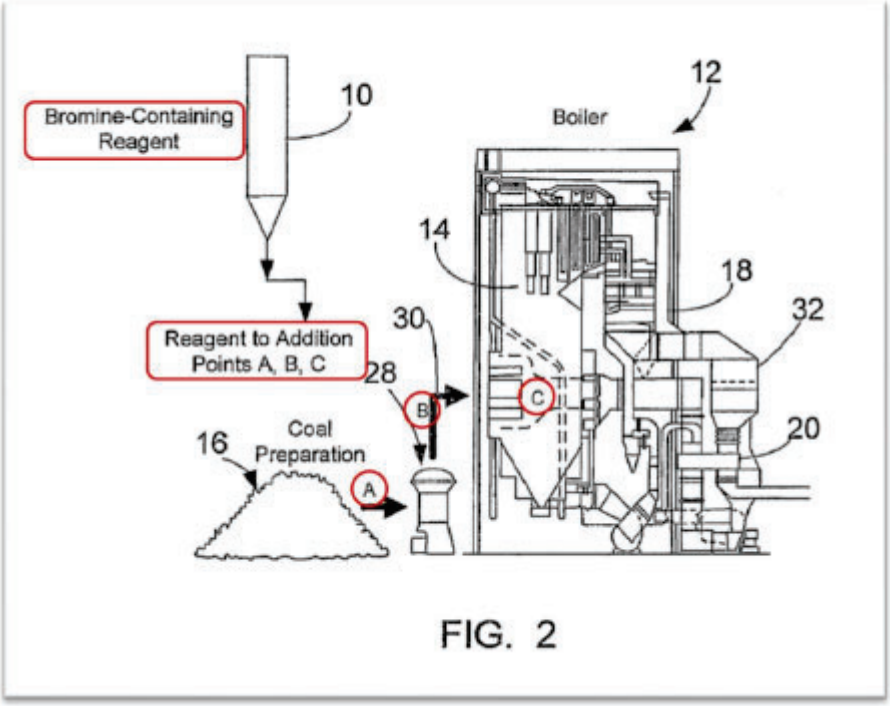


FIG. 2

865. Downs-Boiler in no way restricts introduction to only one type of reagent or introduction to only one of points A, B, and C.[1250]

7. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

866. The language of claim element 18 is substantially identical to the language of claim 6. Accordingly, the explanation I provide above for claim elements 6(a) and 6(b) applies equally to claim element 18.

8. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or

[1250] Ex. 1006 (Downs-Boiler) ¶ [0019]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [0022].

combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility"

867. This limitation is disclosed by Downs-Boiler and would otherwise be obvious based on the background knowledge of a POSITA. Downs-Boiler illustrates a conventional coal-fired facility with a boiler used for the purpose of combusting coal, as represented by the arrow into combustion chamber 14. Representative Figure 4 is reproduced below:[1251]

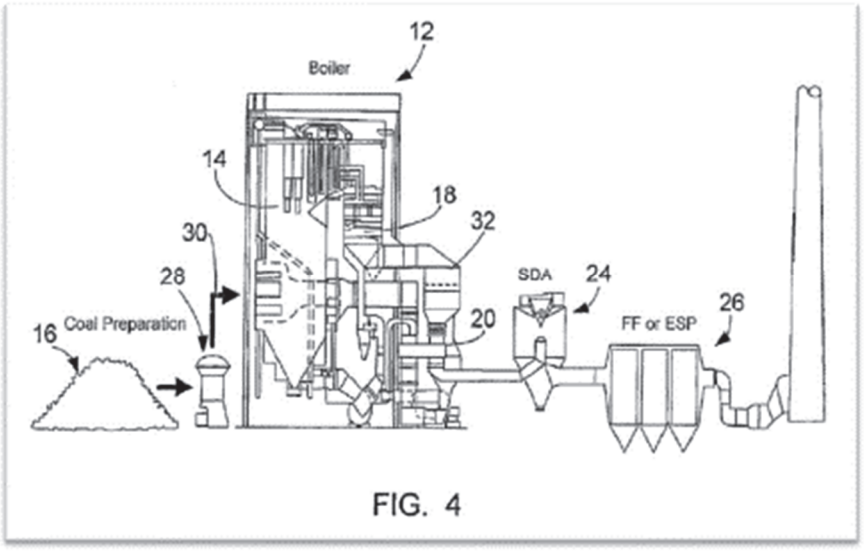


FIG. 4

868. Downs-Boiler goes on to describe such a combustion of coal together with an added bromine-containing reagent, which occurs within combustion chamber 14, as illustrated in Figures 4-6:[1252]

[1251] Ex. 1006 (Downs-Boiler) ¶ [0007], Figures 4; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [009], Figures 4.

[1252] Ex. 1006 (Downs-Boiler) ¶ [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0018].

869. Downs-Boiler illustrates that the bromine-containing reagent may be introduced "to addition points A, B, C" including "coal preparation," "the pulverized coal conveying system 30," and "the boiler furnace 14."[1253]

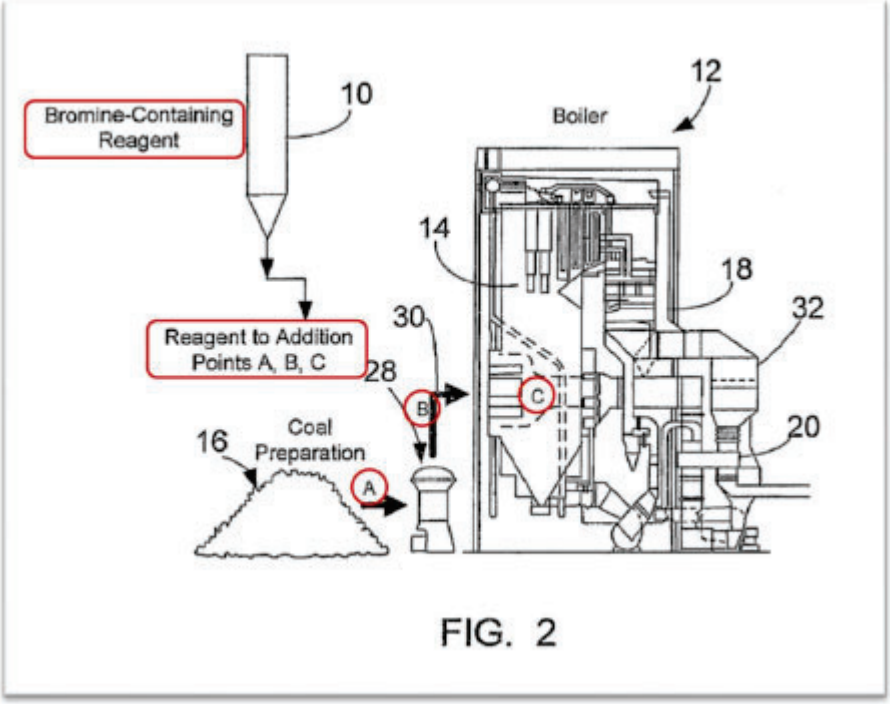


FIG. 2

9. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

870. This limitation is disclosed by Downs-Boiler. Downs-Boiler describes combusting common ranks of coal used by the electric utility industry and, specifically, that "the coal-fired boiler fuel 16 may include bituminous, subbituminous, and lignite coals and blends, thereof."[1254]

[1253] Ex. 1006 (Downs-Boiler) ¶ [0019], Figure 2 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [0022], Figure 2.

[1254] Ex. 1006 (Downs-Boiler) ¶ [0020]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0023].

10. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

871. Downs-Boiler discloses this limitation. As illustrated by Figures 4-6 of Downs-Boiler, representative Figure 6 reproduced below as annotated, Downs-Boiler describes a coal-fired electric utility plant that can have a number of downstream pollution control devices including particulate collection systems (*e.g.,* a fabric filter (FF) system and/or an electrostatic precipitator (ESP) system) (purple) and a scrubber (*e.g.,* wet flue gas desulfurization (FGD) system) (yellow).[1255]

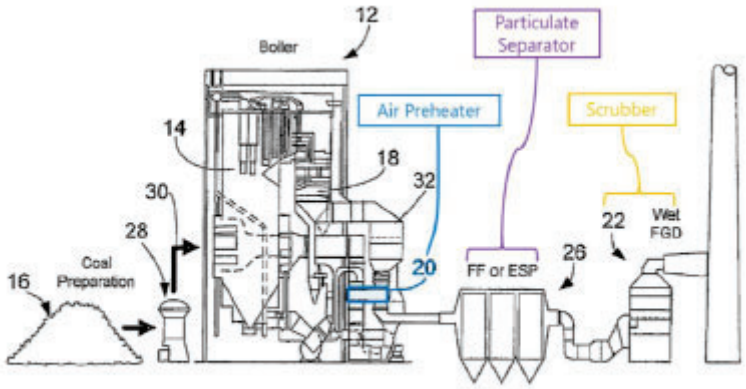


FIG. 6

The use of the bromine-containing reagent as disclosed by Downs-Boiler "thereby enhance[es] the overall removal of mercury in ***downstream pollution***

[1255] Ex. 1006 (Downs-Boiler) Figure 6 (annotated; *see also* Ex. 1006 (Downs-Boiler) Figures 4-5; Ex. 1007 (Downs-Boiler-Provisional) Figures 4-6.

control devices."[1256] Specifically, Downs-Boiler explains that a particular advantage of the disclosed invention is that it "enhances removal of mercury across ***particulate collectors 26*** such as fabric filters (FF) and electrostatic precipitators (ESP)."[1257] As further explained by Downs-Boiler, the upstream injection of a sorbent means that the "sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases ***in a downstream particulate collector***."[1258]

872. The concept of using a particulate collector or a scrubber in conjunction with sorbent injection is further confirmed by the EPA, explaining that for "direct sorbent injection, after sorbent is introduced into the flue gas, it adsorbs Hg and other contaminants and is ***captured downstream*** in an existing or sorbent-specific [(particulate matter)] control device."[1259] Therefore, to the extent Downs-Boiler fails to explicitly disclose injection of the sorbent material into the mercury-containing gas occurring upstream of a particulate collector or a scrubber this would have been obvious to a POSITA at the time.

1256 Ex. 1006 (Downs-Boiler) 11 [0007] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [009].

1257 Ex. 1006 (Downs-Boiler) ¶ [0015] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) II [0018].

1258 Ex. 1006 (Downs-Boiler) ¶ [0004] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [005].

1259 Ex. 1009 (EPA-Proposal) at 4676 (emphasis added).

C. INDEPENDENT CLAIM 14

1. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:

873. The language of the preamble of claim 14 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 14.

2. Claim 14: Element (14a)—"combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas"

874. The language of claim element 14(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 14(a).

875. To the extent that Element 14(a) additionally requires the combusting step be in a combustor, Downs-Boiler discloses this element. Downs-Boiler discloses a combustion chamber (i.e. a "combustion furnace 14") that comprises a "boiler 12."[1260] Furthermore, in Figures 2 and 4-6 Downs-Boiler illustrates a combustion chamber 14 (red) comprising a boiler 12 (green), as indicated by representative Figure 5 reproduced below as annotated:[1261]

[1260] Ex. 1006 (Downs-Boiler) 11 [0015]; *see also* Ex. 1007 (Downs-Boiler-Provisional) IT [0018].

[1261] Ex. 1006 (Downs-Boiler) Figures 2, 4-6; *see also* Ex. 1007 (Downs-Boiler-Provisional) Figures 2, 4-6.

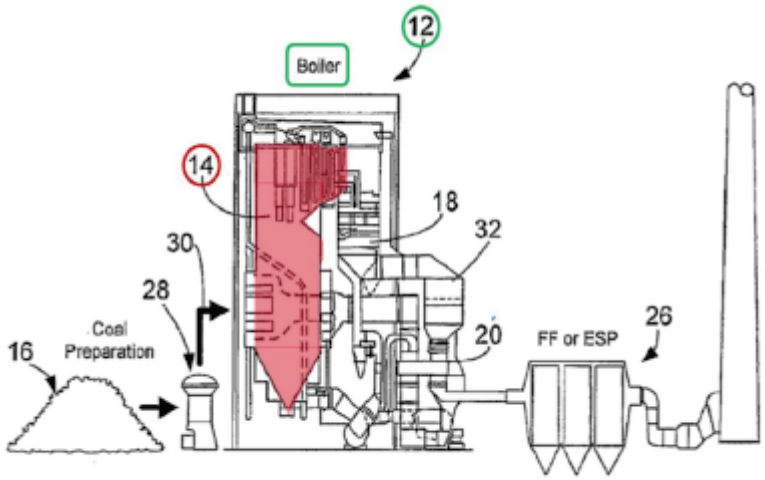


FIG. 5

3. Claim 14: Element (14b)—"and adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

876. The language of claim element 14(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 14(b).

D. CLAIMS DEPENDING FROM CLAIM 14

1. Claim 15: The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char

The language of claim 15 is substantially identical to the language of claim 2. Accordingly, the explanation I provide above for claim 2 applies equally to claim 15.

E. INDEPENDENT CLAIM 17

1. Claim 17: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

877. The language of the preamble of claim 17 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 17.

2. Claim 17: Element (17a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and "

878. The language of claim element 17(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 17(a).

3. Claim 17: Element (17b)—"adding a sorbent material comprising activated carbon into the mercury-containing gas"

The language of claim element 17(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 17(b).

XXVII. GROUND I: OBVIOUSNESS OF THE '225 PATENT OVER DOWNS-BOILER AND EPA-PROPOSAL

879. It is my opinion that Downs-Boiler in view of EPA-Proposal renders obvious claims 5 and 6. Elements and claims not mentioned below are disclosed and/or obvious for the reasons stated in the grounds above.

A. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 5: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

880. In addition to the reasons described in Ground G, claims 2 and 3 would have been obvious over Downs-Boiler in view of the EPA-Proposal. As described in Ground F, Downs-Boiler discloses removing at least 77 wt% of the mercury in the mercury-containing gas.[1262] Downs-Boiler also discloses removing mercury to meet advancing EPA standards regulating mercury emissions from coal-fired plants.[1263] The EPA proposed rules stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018" with more near-term caps built in.[1264]

881. A POSITA would have been motivated to target at least this desired level in order to comply with these upcoming federal mercury emissions standards and, as such, would have selected a rate of removing mercury from the mercury containing gas of at least that mandated by the EPA—removing greater than 70% of the mercury from the flue gas. The EPA's announcement of its forthcoming strict regulations that mercury emissions of coal-fired utility boilers must be abated by 70%

[1262] Ex. 1006 (Downs-Boiler) Figure 3 (annotated); *see also* Ex. 1007 (Downs-Boiler-Provisional) Figure 3.

[1263] Ex. 1006 (Downs-Boiler) ¶ [0001]; *see also* Ex. 1007 (Downs-Boiler-Provisional) 11 [002].

[1264] Ex. 1009 (EPA-Proposal) at 4698.

exerted a strong outside impetus on the industry. As a result, there was a great need to meet or exceed those compliance limits being driven by the governmental regulations that rendered obvious the limitation of removing greater than 70 wt % of the mercury in the mercury-containing gas. Accordingly, a POSITA would have been motivated to target at least this 70% emissions reduction as a "desired level" of mercury removal from the mercury-containing gas.

2. Claim 6: "The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof.""

882. As described above in the discussion of Downs-Boiler, Downs-Boiler monitors mercury content and controls injection rate of bromine and/or a bromide compound. The EPA-Proposal discusses an additional control variable that can be used to adjust mercury content in the mercury-containing gas. Regarding claim element l(f)(1), it would have been obvious for a POSITA to also continuously adjust the injection rate of the sorbent into the mercury-containing gas in order to achieve the desired mercury emissions targets (discussed in the subsection above). As discussed by the EPA, when using sorbents such as activated carbon, the "extent of potential Hg removal is dependent on: (1) Efficient distribution of the sorbent (e.g., activated carbon) in the flue gas; (2) *the amount of sorbent needed* to achieve a specific level of Hg removal which will vary depending on the fuel being

burned."[1265] Accordingly, in operating a dry-emission control system, such as the electrostatic precipitator and/or fabric filter as in Downs-Boiler, a POSITA would have been motivated to continuously adjust an injection rate of the sorbent into the mercury-containing gas, in response to the continuous monitoring of the mercury level, to provide the desired amount of sorbent needed to remove mercury.

XXVIII. GROUND J: OBVIOUSNESS OF THE '225 PATENT OVER DOWNS-BOILER AND NELSON

883. It is my opinion that Downs-Boiler in view of Nelson renders obvious each of claims 5 and 27. Elements and claims not mentioned below are disclosed and/or obvious for the reasons stated in the grounds above.

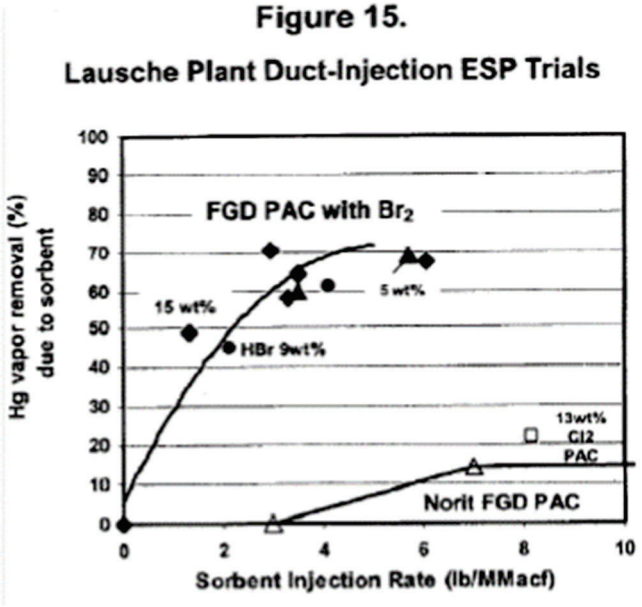
A. CLAIM DEPENDING FROM CLAIM 1

1. Claim 5: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

884. In addition to the reasons described above from the disclosures in Downs-Boiler, Claim 5 would have been obvious over Downs-Boiler in view of Nelson. For example, as explained above with respect to claim 5, Downs-Boiler illustrates removing at least 77% of the mercury from the mercury-containing gas in Figure 3. Through routine process optimization, a POSITA would have been able to adjust the bromine:sorbent ratio such that at least 70% of the mercury is in the mercury-containing gas is removed on the sorbent. Downs-Boiler recognizes that

[1265] Ex. 1009 (EPA-Proposal) at 4676 (emphasis added).

there are a number of factors, such as "combustion air preheater temperature profiles, flue gas composition, fly ash characteristics and composition, and the presence of unburned carbon have all been shown to affect the conversion of elemental mercury to oxidized mercury species."[1266] A POSITA would have looked to Nelson to answer a number of these factors; for example, Nelson also conducted a study to determine the mercury removed by the sorbent itself, as opposed to other components such as unburnt carbon or a scrubber. Figure 15 of Nelson plots the "Hg vapor removal (%) *due to sorbent,"* and the X-axis plots the sorbent injection rate.



885. At a sorbent injection rate of approximately 4 lb/MMacf, Nelson achieves above 70% removal by the sorbent itself.[1267] And based on the trending

[1266] Ex. 1006 (Downs-Boiler) ll [0005]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ll [006].

[1267] Ex. 1012 (Nelson) at 15:35-38.

curve, a POSITA would have recognized that at a sorbent injection rate of 5 lb/MMacf, the sorbent itself would have removed even more than 70% mercury. Accordingly, a POSITA would have been motivated to, and capable of, using the processes disclosed in Nelson and Downs-Boiler to remove 70% or more mercury from the mercury-containing flue gas, including on the sorbent.

2. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

886. In addition to the reasons described above from the disclosures in Downs-Boiler, Claim 27 would have been obvious over Downs-Boiler in view of Nelson. Downs-Boiler describes "particulate collectors" including electrostatic precipitators (ESP) and ***fabric filters (FF)*** that "provide high-efficiency removal of particulate-bound mercury."[1268] Particularly, Downs-Boiler states that "[f]abric filters tend to exhibit better particulate laden mercury removal."[1269] Downs-Boiler discloses that the activated-carbon sorbent is injected into the mercury-containing flue gas such that it is subsequently "removed from the flue gases in a ***downstream***

[1268] Ex. 1006 (Downs-Boiler) 11 [0003]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ¶ [004].

[1269] Ex. 1006 (Downs-Boiler) ¶ [0003]; *see also* Ex. 1007 (Downs-Boiler-Provisional) ill [004].

particulate collector."[1270] Similarly, Nelson also discloses an embodiment in which "sorbent flows with flue gas to a fabric filter 31 and is deposited on the filter bags in a filter cake along with the fly ash and other gas-stream particulates," which also causes "intimate contact between the sorbents and the remaining mercury in the flue gas."[1271] The "mercury sorbents in the filter cake" are removed, and "[c]leansed of its mercury content and particulates, the flue gas exits the fabric filter."[1272] Accordingly, Nelson clarifies the disclosure of Downs-Boiler, explaining that the activated-carbon sorbent would have been injected upstream of a particulate collector (such as a fabric filter).

887. Downs-Boiler also describes an embodiment in which an electrostatic precipitator (ESP) is used as a particulate collector.[1273] However, Downs-Boiler does not expressly state the injection location of activated-carbon sorbent for such an embodiment. A POSITA would have used the disclosure of Nelson to clarify the disclosure of Downs-Boiler, particularly, where to inject the activated-carbon sorbent for coal-fired utility plant configured with an ESP. Nelson describes injecting "sorbents to a plant which has a 'hot-side' ESP, a particularly difficult situation for

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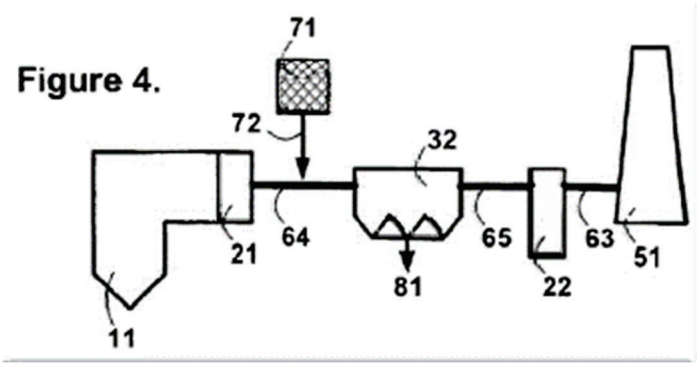
[1270] Ex. 1006 (Downs-Boiler) ¶ [0004] (emphasis added); *see also* Ex. 1007 (Downs-Boiler-Provisional) 411 [005].

[1271] Ex. 1012 (Nelson) at 9:36-42

[1272] Ex. 1012 (Nelson) at 9:43-50

[1273] Ex. 1006 (Downs-Boiler) ¶ [0003]; *see also* Ex. 1007 (Downs-Boiler-Provisional) III [004].

mercury control.[1274] In this equipment arrangement, the air preheater 22 follows the ESP 32.[1275]



888. Nelson discloses that in such a configuration, as shown in Figure 4, the activated carbon is injected "from bin 71," which is upstream from a particulate collector (item 32).[1276] Accordingly, Nelson clarifies the disclosure of Downs-Boiler in that for a plant with a hot-side ESP followed by a pre-heater, the injection of activated carbon would have been upstream of both.

XXIX. GROUND K: OBVIOUSNESS OF THE '225 PATENT OVER SJOSTROM AND OLSON-646

889. It is my opinion that Sjostrom in view of Olson-646 render obvious each of the asserted claims of the '225 Patent.

A. INDEPENDENT CLAIM 1

1. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising: "

1274 Ex. 1012 (Nelson) at 10:9-11.
1275 Ex. 1012 (Nelson) at Figure 4, 10:9-13
1276 Ex. 1012 (Nelson) at 10:20-22.

890. As discussed regarding the preamble of claim 1, in Ground G above, the preamble is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

2. Claim 1: Element (1)(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and"

891. As discussed in Ground G above, this limitation is disclosed and/or rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

892. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. To the extent that Sjostrom does not explicitly identify the specific bromine-containing species used, Olson-646 teaches this limitation. Olson-646 "provides a cost-effective way to capture pollutants by utilizing exceptionally reactive halogen/halide promoted carbon sorbents using a bromide (or other halogen/halide) treatment of the carbon, that capture mercury via mercury-sorbent surface reactions, at very short contact times of seconds or less."[1277] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1278] As described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a

[1277] Ex. 1014 (Olson-646) at ¶ [0043].
[1278] Ex. 1014 (Olson-646) at ¶ [0066].

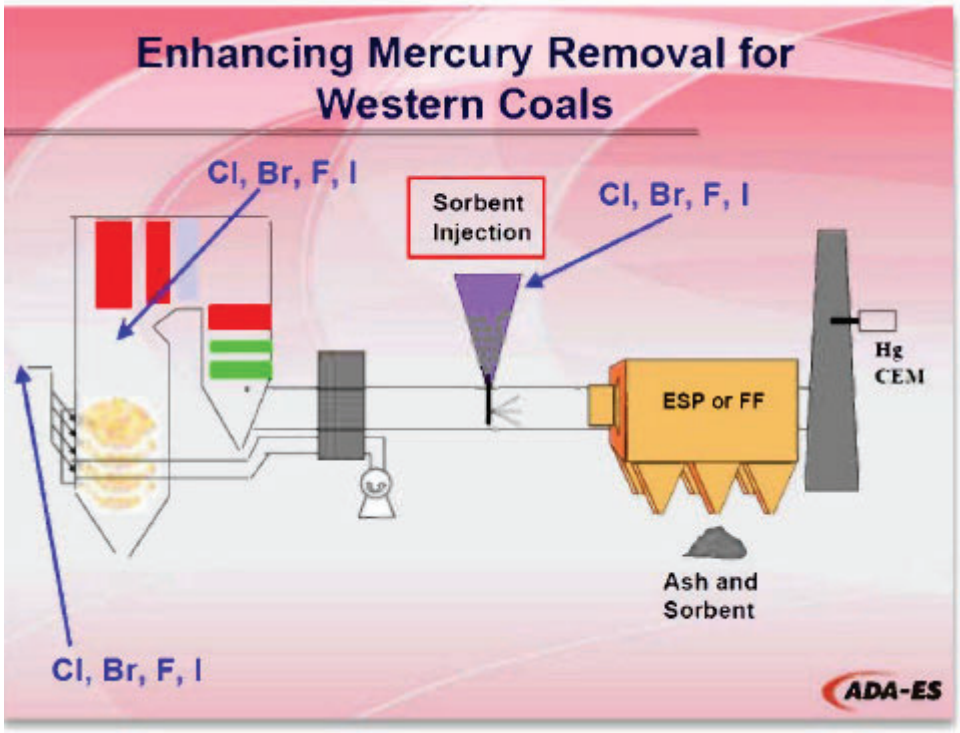
reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom.

893. I understand that under the Plaintiffs' theory of infringement in this case, and consistent with the Court's claim construction ruling, combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof does not require the addition of pyrolysis char to system. I understand that under this theory this claim element of pyrolysis char as it appears in Claim 1 is met if the combustion of coal produces some pyrolysis char, even briefly. I agree with Defendants that some pyrolysis char will be formed whenever coal is being combusted, including in the combustion systems disclosed in Sjostrom and Olson-646.

3. Claim 1: Element (1)(c)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

894. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[1279]

[1279] Ex. 1010 (Sjostrom) at 4 (annotations in red).



As shown in the above figure, the "Sorbent Injection" occurs downstream from a combustion chamber. Specifically, Sjostrom described testing performed with activated carbon injection, including injection of "DARCO FGD."[1280] A POSITA would have understood that DARCO FGD was a well-known type of activated carbon used for mercury capture.[1281]

895. Similarly, Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream."[1282] The "contaminated flue gas stream" refers to a stream of mercury-containing gas.

[1280] Ex. 1010 (Sjostrom) at 10, 11, 16.
[1281] See, e.g., State of the Art, Sections XII.C.3, XII.G.2.
[1282] Ex. 1014 (Olson-646) at ¶ [0061].

B. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char

896. As discussed for Claim 2 in Ground G above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

2. Claim 5: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

897. As discussed in Ground G above, this limitation is disclosed and/or rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

898. In addition, this claim is also obvious over Sjostrom in view of Olson-646. For example, Olson-646 explains that "a method is provided for reducing mercury in flue gas comprising providing a sorbent, injecting the sorbent into a mercury-containing flue gas stream, ***collecting greater than 70 wt% of the mercury in the flue gas on the sorbent*** to produce a cleaned flue gas, and substantially recovering the sorbent from the cleaned flue gas."[1283] Claim 30 of Olson-646 also discloses "comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."[1284]

[1283] Ex. 1014 (Olson-646) at ¶ [0022] (emphasis added).
[1284] Ex. 1014 (Olson-646) at Claim 30.

3. Claim 6: Element (6)(a)—"The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and "

899. As discussed for Elements 6(a) in Ground G above, this element is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

4. Claim 6: Element 6(b)

a. Element (6b)—"modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

900. As discussed for Elements 6(b) in Ground G above, this element is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

5. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

901. As discussed for claim 8 in Ground G above, this element is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

6. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

902. As discussed for claim 8 in Ground G above, this element is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

903. In addition, Olson-646 discloses than an "optional alkali material, including without limitation alkaline and alkaline earth components" can be add in its method.[1285] This optional alkaline component is also claimed in Olson-646.[1286]

7. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

904. The language of claim element 18 is substantially identical to the language of claim 6. Accordingly, the explanation I provide above for claim elements 6(a) and 6(b) applies equally to claim element 18.

8. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility"

[1285] Ex. 1014 (Olson-646) at ¶¶ [0026, 0061].
[1286] Ex. 1014 (Olson-646) at Claims 23, 24, 25, 39, 40.

905. As discussed for claim 20 in Ground G above, this element is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

906. In addition, Olson-646 teaches that the addition of bromine to the coal at the coal combustion facility has several benefits over treating sorbents off-site, included lower capital equipment and transport costs.[1287]

9. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

907. As discussed for claim 25 in Ground G above, this element is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

908. In addition, Olson-646 discloses that its methods can be used on combustors burning subbituminous coal.[1288]

10. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

[1287] Ex. 1014 (Olson-646) at ¶¶ [0078-0087].
[1288] Ex. 1014 (Olson-646) at ¶ [0106].

909. As discussed for claim 25 in Ground G above, this element is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground G applies equally here.

910. In addition, Olson-646 discloses the use of particulate control systems such as baghouses, ESPs, or scrubbers.[1289]

C. INDEPENDENT CLAIM 14

1. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:

911. The language of the preamble of claim 14 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 14.

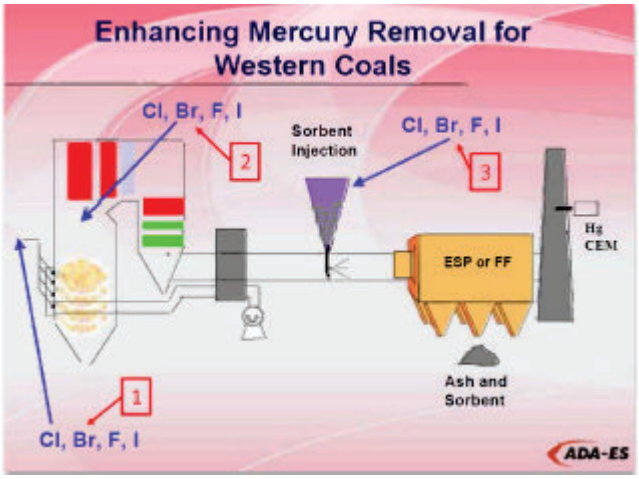
2. Claim 14: Element (14a)—"combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas"

912. The language of claim element 14(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 14(a).

913. To the extent that Element 14(a) additionally requires the combusting step be in a combustor, Sjostrom discloses this element. Sjostrom discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing

[1289] Ex. 1014 (Olson-646) at ¶ [0123].

flue gas stream. Addition Location 2 shows addition of a halogen additive into the combustor.[1290]



3. Claim 14: Element (14b)—"and adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

914. The language of claim element 14(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 14(b).

D. CLAIMS DEPENDING FROM CLAIM 14

1. Claim 15: The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char

The language of claim 15 is substantially identical to the language of claim 2. Accordingly, the explanation I provide above for claim 2 applies equally to claim 15.

[1290] Ex. 1010 (Sjostrom) at 4 (annotations in red).

E. INDEPENDENT CLAIM 17

1. Claim 17: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

915. The language of the preamble of claim 17 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 17.

2. Claim 17: Element (17a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and "

916. The language of claim element 17(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 17(a).

3. Claim 17: Element (17b)—"adding a sorbent material comprising activated carbon into the mercury-containing gas"

917. The language of claim element 17(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 17(b).

XXX. GROUND L: ANTICIPATION OF THE '225 PATENT OVER VOSTEEN AND/OR OBVIOUSNESS OVER VOSTEEN IN COMBINATION WITH GRANITE

918. It is my opinion that Vosteen either alone or in combination with the background knowledge of a POSITA or Granite renders obvious each of asserted claim of the '225 Patent.

A. INDEPENDENT CLAIM 1

1. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising: "

919. Vosteen discloses the preamble. The title of Vosteen is, "Process for removing mercury from flue gases."[1291] Flue gas is an example of a mercury-containing gas, and "removing mercury" refers to separating the mercury from a mercury-containing gas. Vosteen describes "removal of mercury from the flue gases in a flue gas emission control system downstream of the combustion," in plants such as "power stations, for example bituminous coal-fired or lignite-fired power stations.[1292] Claims 1 and 18 of Vosteen also discloses the preamble.

2. Claim 1: Element (1)(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

920. Vosteen discloses this claim element. Vosteen discloses that one of the applications for his process is in removing mercury from a mercury-containing gas

1291 Ex. 1008 (Vosteen) at Title.

1292 Ex. 1008 (Vosteen) at 2:16-20, 2:35-37.

generated from the combustion of coal in a combustion chamber. For example, Vosteen describes experiments conducted on "a *coal-fired power station* of Bayer AG in Uerdingen, which essentially consists of *a slag-tap fired boiler*."[1293] Vosteen also describes a *"coal-fired* power station of Bayer AG in Uerdingen (see FIG.9)" with "two parallel slag-tap fired boilers 91, 92 having temperatures in the *combustion chamber* around 1450°C."[1294] Vosteen describes his results in Figures 7 and 8 regarding the experiments conducted on "coal combustion (bituminous coal)."[1295] This limitation is also disclosed in claims 1 and 18 of Vosteen.

921. Vosteen describes adding HBr (hydrogen bromide) and bromide compounds to the coal, or to the combustion chamber, or both. Sodium bromide is an example of a bromide compound. Vosteen describes that bromine-containing ingredients are added to the combustion chamber (also referred to by Vosteen as a furnace), and can also be added to the coal upstream of the combustion chamber.

> The invention relates to a process for removing mercury from flue gases of high-temperature plants, in particular from power stations and waste incineration plants, *in which bromine and/or a bromine compound and/or a mixture of various bromine compounds is fed to*

1293 Ex. 1008 (Vosteen) at 7:25-28.
1294 Ex. 1008 (Vosteen) at 10:63-11:6.
1295 Ex. 1008 (Vosteen) at 11:23-24.

the if appropriate multistage furnace and/or to the flue gas in a plant section downstream of the furnace .[1296]

Particularly preferably, an *aqueous solution of hydrogen bromide or an alkali metal bromide,* in particular sodium bromide, or an aqueous solution of the alkali metal bromide is used.[1297]

The *bromine compound*, for example, *sodium bromide, can be added in solid form, for example as salt, or in liquid form,* for example as aqueous solution, *to the* waste mixture, *coal or the like to be burnt, upstream of the furnace.* The addition can also be *made to a plant section upstream of the furnace*, for example a pyrolysis drum, which serves, for example, for the thermal breakdown of co-incinerated waste materials, or *to a coal mill*. *The compound can also be fed during the combustion process*. . . .*[T] he bromine compound can be introduced*, likewise in solid or liquid form, *into one or both combustion chambers*, for example into the rotary kiln and/or the afterburning chamber. Preferably, an aqueous solution

1296 Ex. 1008 (Vosteen) at 1:65-2:5.
1297 Ex. 1008 (Vosteen) at 2:58-61.

> of the compound is *sprayed into one of the combustion chambers*.[1298]
>
> [I]t is also possible to feed the bromine compound, for example an *aqueous solution of hydrogen bromide or sodium bromide*, at a fine dispersion *to the combustion* air and/or if appropriate to a recirculated substream, in particular recirculated flue gas, recirculated ash and recirculated fly ash.[1299]

The "bromine and/or a bromine compound" identified above in Vosteen refers to molecular bromine (Br_2) and/or a compound containing the element bromine (Br) bonded to other chemical elements. This claim element is also disclosed by claims 1 and 2 of Vosteen, highlighted below, which recite adding a bromine compound or mixture of compounds (including hydrogen bromide) to the combustion chamber (furnace), as well as claim 18.[1300]

922. I understand that under the Plaintiffs' theory of infringement in this case, and consistent with the Court's claim construction ruling, combusting a mixture of comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof does not require the separate addition of

1298 Ex. 1008 (Vosteen) at 4:4-19.
1299 Ex. 1008 (Vosteen) at 4:28-33.
1300 Ex. 1008 (Vosteen) at Claims 1, 2, 18.

pyrolysis char to system. I understand that under this theory this claim element of pyrolysis char as it appears in Claim 1 is met if the combustion of coal produces some pyrolysis char, even briefly. I agree with Defendants that some pyrolysis char will be formed whenever coal is being combusted, including in the combustion systems disclosed inVosteen. Accordingly, the combusting of coal with added bromine reagent disclosed in Vosteen is the combusting of coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas.

3. Claim 1: Element (1)(c)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

923. Vosteen discloses a dry-emission control system that includes injecting an activated-carbon sorbent for adsorbing mercury into a mercury-containing gas. Vosteen describes "cloth filters which are impinged with a blown-in finely pulverulent slaked lime/ *activated carbon* or slaked lime/lignite coal coke mixture."[1301] These fabric filters are inserted into the flue gas stream.

924. As I describe in the State of the Art regarding Components Downstream of the Combustion Chamber, fabric filters have been a component of downstream emissions control that contain fabric bags. They are placed into the flue gas stream, such that the mercury-containing flue gas with fly ash pass through the bags, and

[1301] Ex. 1008 (Vosteen) at 5:27-30.

particle materials are filtered out of the gas. Vosteen describes adding bromine-containing species to the coal (and/or or to the combustion chamber) to introduce HBr and other bromine-containing species into the mercury-containing flue gas generated in the combustion chamber, and also describes injecting a mixture of lime and activated carbon onto fabric filters downstream of the combustion chamber.[1302] This treatment configuration spontaneously brominates the activated carbon (sorbent) in the mercury-containing flue gas as both the activated-carbon sorbent and the bromine-containing species move towards the fabric filter unit. The bromination also occurs in the dust cakes of fly ash, activated carbon, and lime on the outer bag surfaces. In turn, the brominated activated carbon captures elemental and oxidized mercury at extremely high efficiency, due to the large concentration of brominated sites in the activated carbon in a dust cake.

925. It would have also been obvious to combine Vosteen's addition of bromine compounds to coal for combustion with activated carbon injection systems in use at the time that the Vosteen reference was published. For example, Vosteen's bromine additive would have been obvious to use in the plants described in the Granite reference. Granite explains that control technologies for removing mercury from flue gas at the time include the use of activated carbon sorbents injected into the

[1302] Ex. 1008 (Vosteen) at 5:27-30.

gas stream.[1303] Granite describes, for example, the activated carbon duct injection systems used for mercury control for industrial combustors.[1304] A POSITA would understand that injection of activated carbon into the flue was the more common and readily available method of using activated carbon for mercury control instead of the impinged fabric filters of Vosteen. Furthermore, a POSITA would have been motivated by Granite's teaching that the promotion of activated carbon using halogens such as chlorine and iodine to combine the teachings of Vosteen regarding bromine with the state of the art activated carbon systems it describes.[1305]

B. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char

926. As described for Claim 1, the char present in the combustion mixture is the char present from the combusting of coal. As described for Claim 1, Vosteen describes the addition of the claimed bromine species to coal for combustion. According to Defendants' own theories of infringement, the formation of char during the combustion of coal in the presence of bromine will lead to the formation of some promoted pyrolysis char.

2. Claim 5: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

[1303] Ex. 2003 (Granite 2000) at 1020, 1022.
[1304] Ex. 2003 (Granite 2000) at 1026.
[1305] Ex. 2003 (Granite 2000) at 1020.

927. Vosteen renders this claim obvious in combination with the background knowledge of a POSITA. Vosteen discloses maintaining mercury levels below those needed to comply with legal and regulatory requirements.[1306] Vosteen describes measuring the mercury content and then, in response to that measurement, controlling process parameters (e.g., rates of addition of bromine-containing components) to achieve those limits. Measurements of the mercury content are depicted in Figures 2-8 of Vosteen,[1307] and also recited in claim 9 of Vosteen.[1308] Vosteen further describes maintaining mercury content of the cleaned gas below desired levels, including those imposed by regulatory authorities. For example, Vosteen mentions that "strict limiting values exist for the legally permissible emission of mercury, for example from incineration plants and power stations."[1309] Vosteen discusses the need that his invention provided a solution for "further reduction of the currently permitted limiting values" of mercury emissions.[1310]

928. As I discuss in the State of the Art, the EPA and other regulatory bodies proposed rules that, upon implementation, would have required mercury emissions reductions by 70%. In trying to ensure their plants were compliant upon eventual implementation and promulgation of the EPA rules, a person of skill in the art would

1306 Ex. 1008 (Vosteen) at 1:10-13, 1:20-22.
1307 Ex. 1008 (Vosteen) at Figs. 2-8.
1308 Ex. 1008 (Vosteen) at Claims 9.
1309 Ex. 1008 (Vosteen) at 1:10-13.
1310 Ex. 1008 (Vosteen) at 1:20-22.

have been motivated, and it would have been obvious, to keep mercury emissions below the desired levels proposed by the EPA in order to avoid paying regulatory fines and other penalties that would incur upon rule implementation.

3. Claim 6: Element (6)(a)—"The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and "

929. Vosteen discloses this claim element. Vosteen describes that "*the mercury content of the flue gas*, in particular the content of metallic [i.e., elemental] mercury, *is measured continuously* downstream of the flue gas emission control system."[1311] Measurements of the mercury content are depicted in Figures 2-8 of Vosteen,[1312] and are also recited in claim 9 of Vosteen.[1313]

4. Claim 6: Element 6(b)

a. Element (6b)—"modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

930. Vosteen discloses this claim element. Vosteen monitors the mercury content of the cleaned gas, and in response, controls the amount of addition to the coal and/or combustion chamber of the added bromine-containing species.

> Preferably, in the inventive process, *the mercury content of the flue gas*, in particular the content of metallic mercury, *is measured continuously* downstream of the flue gas emission

1311 Ex. 1008 (Vosteen) at 5:48-50.
1312 Ex. 1008 (Vosteen) at Figs. 2-8.
1313 Ex. 1008 (Vosteen) at Claims 9.

> control system and *on the basis of the measured mercury content the amount of bromine fed and/or bromine compounds and/or the mixture of bromine compounds* and if appropriate sulphur and/or sulphur substances and/or the mixture of sulphur substances *is controlled.*[1314]

931. As explained above, the bromine-containing species include aqueous hydrogen bromide [HBr(aq)], bromide compounds in solid or aqueous form (e.g., sodium bromide [NaBr(s) or NaBr(aq)], molecular bromine (Br_2), and mixtures thereof, and these bromine-containing species are added to either the coal or to the combustion chamber. Claim Element 28(b) is also disclosed by claim 9 of Vosteen.[1315]

5. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

932. Vosteen discloses this element. The sorbent material used by Vosteen is granular activated carbon: "fixed-bed adsorbers, for example based on granulated activated carbon."

933. Granite also discloses a number of different types of activated carbon.

6. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements,

1314 Ex. 1008 (Vosteen) at 5:48-55.
1315 Ex. 1008 (Vosteen) at Claims 9.

alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

934. Vosteen discloses this element. For example, Vosteen teaches that the flue gas control system can be used with additional alkaline sorbents including granular lime, such as in a mixture with adsorbers like activated carbon.[1316]

7. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

935. The language of claim element 18 is substantially identical to the language of claim 6. Accordingly, the explanation I provide above for claim elements 6(a) and 6(b) applies equally to claim element 18.

8. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility"

936. This limitation is disclosed by Vosteen. Vosteen explains that the addition of the bromine compound to coal can be made at the plant, upstream of the furnace.[1317]

9. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

[1316] Ex. 1008 (Vosteen) at 5:15-49; 7:25-31.
[1317] Ex. 1008 (Vosteen) at 3:66-4:13.

937. This claim element is obvious in light of Vosteen and the background knowledge of a POSITA. Vosteen teaches that its invention can be applied to coal-fired power stations using a variety of coals.[1318]

10. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

938. Vosteen discloses this claim element. Vosteen describes numerous components that are used to separate the mercury/sorbent composition from the mercury-containing (flue) gas, to form a cleaned gas. Such components include a spray-dryer adsorber (SDA), electrostatic precipitator (ESP), or fabric filter.[1319] These are also discussed in claims of Vosteen.[1320]

939. Vosteen repeatedly refers to a flue gas *cleaning* system.[1321] Vosteen refers to "clean gas downstream of the wet and/or dry flue gas emission system."[1322] This is because, as Vosteen discloses, an "object of the invention to provide a process for removing mercury, in particular for the substantially complete removal of

[1318] Ex. 1008 (Vosteen) at 2:32-53.
[1319] Ex. 1008 (Vosteen) at 5:15-30.
[1320] Ex. 1008 (Vosteen) at Claim 10.
[1321] See, e.g., Ex. 1008 (Vosteen) at Abstract, 2:12-15, 5:1-5.
[1322] Ex. 1008 (Vosteen) at 6:2-4.

mercury (Hg)."[1323] Granite also describes scrubbing solutions for removal of sorbents.[1324]

940. A POSITA would understand that the addition of a sorbent must occur before the scrubber or particulate control system, as the purpose of the sorbent is to adsorb gaseous pollutants such as mercury so that the pollutants can be removed on the particulates by the scrubber or particulate control system.

C. INDEPENDENT CLAIM 14

1. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:

941. The language of the preamble of claim 14 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 14.

2. Claim 14: Element (14a)—"combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas"

942. The language of claim element 14(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 14(a).

[1323] Ex. 1008 (Vosteen) at 1:50-53.

[1324] Ex. 2003 (Granite 2000) at 1020, 1026.

943. To the extent that Element 14(a) additionally requires the combusting step be in a combustor, Vosteen discloses this element. Vosteen continuously refers to combustion happening in a combustion chamber.[1325]

3. Claim 14: Element (14b)—"and adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

944. The language of claim element 14(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 14(b).

D. CLAIMS DEPENDING FROM CLAIM 14

1. Claim 15: The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char

The language of claim 15 is substantially identical to the language of claim 2. Accordingly, the explanation I provide above for claim 2 applies equally to claim 15.

E. INDEPENDENT CLAIM 17

1. Claim 17: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

945. The language of the preamble of claim 17 is identical to the language of the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 17.

[1325] Ex. 1008 (Vosteen) at 4:4-19; 10:64-11:5.

2. Claim 17: Element (17a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and "

946. The language of claim element 17(a) is substantially identical to the language of claim element 1(a). Accordingly, the explanation I provide above for claim element 1(a) applies equally to claim element 17(a).

3. Claim 17: Element (17b)—"adding a sorbent material comprising activated carbon into the mercury-containing gas"

947. The language of claim element 17(b) is substantially identical to the language of claim element 1(b). Accordingly, the explanation I provide above for claim element 1(b) applies equally to claim element 17(b).

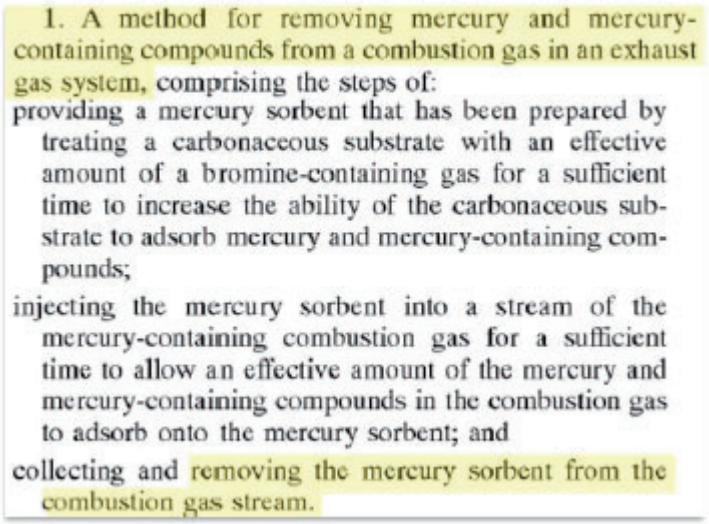
XXXI. GROUND M: OBVIOUSNESS OF THE '147 PATENT OVER NELSON ALONE OR IN VIEW OF OLSON-PAPER AND/OR LISSIANSKI-PATENT

948. It is my opinion that Nelson either alone or in combination with the Olson-Paper and/or Lissianski-Patent anticipates and/or renders obvious claims 17-20 of the '147 patent, as independent claim 1 on which those claims depend.

A. CLAIM 1

1. Claim 1: Preamble — "A method for separating mercury from a mercury containing gas comprising:"

949. The preamble is disclosed by Nelson. Nelson repeatedly describes separating, or removing, mercury from a mercury containing gas. This can be seen in claim 1 of Nelson[1326]



1. A method for removing mercury and mercury-containing compounds from a combustion gas in an exhaust gas system, comprising the steps of:

providing a mercury sorbent that has been prepared by treating a carbonaceous substrate with an effective amount of a bromine-containing gas for a sufficient time to increase the ability of the carbonaceous substrate to adsorb mercury and mercury-containing compounds;

injecting the mercury sorbent into a stream of the mercury-containing combustion gas for a sufficient time to allow an effective amount of the mercury and mercury-containing compounds in the combustion gas to adsorb onto the mercury sorbent; and

collecting and removing the mercury sorbent from the combustion gas stream.

950. In addition, the title of Nelson is "Sorbents and Methods for the Removal of Mercury from Combustion Gases."[1327] The Abstract of Nelson further describes that the patent provides a "method for removing mercury and mercury-containing compounds from a combustion gas in an exhaust gas system."[1328] The "combustion gas" is a mercury-containing gas, and the mercury is separated from that gas. Nelson teaches that the mercury is separated from the mercury containing gas when "an effective amount of the mercury and mercury-containing compounds in the

1326 Ex. 1012 (Nelson) at claim 1.
1327 Ex. 1012 (Nelson) at Title.
1328 Ex. 1012 (Nelson) at Abstract.

combustion gas ... adsorb onto the mercury sorbent."[1329] Nelson further states that the Field of the Invention "relates to the removal of mercury from combustion gas streams."[1330] Nelson provides numerous other disclosures of separating mercury from a mercury-containing gas.[1331]

951. As additional evidence that a POSITA would have had a reasonable expectation of success in applying the teachings of Olson-Paper to Nelson, Olson-Paper also teaches separating mercury from a mercury containing gas. The title of Olson-Paper is "Chemical mechanisms in *mercury emission control* technologies.[1332] Olson-Paper further explains in the Abstract:

> The *emission of elemental mercury* in the flue gas from coal-burning power plants is a major environmental concern. Control technologies utilizing activated carbon show promise and are currently under intense review. *Oxidation and capture of elemental mercury on activated carbon was extensively investigated in a variety of flue gas atmospheres.*[1333]

The "capture of elemental mercury on activated carbon" refers to separating the mercury from the mercury-containing flue gas by adsorbing it onto activated carbon.

2. Claim 1: Element 1(a)(1) — "promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a

---

1329 Ex. 1012 (Nelson) at Abstract.
1330 Ex. 1012 (Nelson) at 1:24-27.
1331 *See, e.g.,* Ex. 1012 (Nelson) at 4:31-35 ("object of the present invention" of Nelson), 15:65-67 & 16:7-13 (claim 1), 18:23-26 (claim 29), Figs. 7-15.
1332 Ex. 1079 (Olson-Paper) at Title.
1333 Ex. 1079 (Olson-Paper) at Abstract (emphasis added).

bromine containing promoter to form a promoted brominated sorbent."

952. This limitation is disclosed by Nelson. Nelson discloses promoting powdered activated-carbon (PAC) sorbent by chemically reacting the PAC with bromine-containing gases (e.g., Br_2 and/or HBr) to form a promoted brominated sorbent. This can be seen in claims 1 and 3 of Nelson, highlighted below:[1334]

1. A method for removing mercury and mercury-containing compounds from a combustion gas in an exhaust gas system, comprising the steps of:

providing a mercury sorbent that has been prepared by treating a carbonaceous substrate with an effective amount of a bromine-containing gas for a sufficient time to increase the ability of the carbonaceous substrate to adsorb mercury and mercury-containing compounds;

injecting the mercury sorbent into a stream of the mercury-containing combustion gas for a sufficient time to allow an effective amount of the mercury and mercury-containing compounds in the combustion gas to adsorb onto the mercury sorbent; and

collecting and removing the mercury sorbent from the combustion gas stream.

3. The method of claim 2, wherein:

the carbonaceous substrate comprises activated carbon.

Claims 10 and 17 of Nelson also recite that "the carbonaceous substrate comprises activated carbon."[1335] Claims 19 and 22 of Nelson further recite using activated

[1334] Ex. 1012 (Nelson) at claims 1, 3.
[1335] Ex. 1012 (Nelson) at claims 10, 17.

carbon as the sorbent, and reacting the activated carbon with a bromine-containing gas.[1336]

953. Nelson discloses preparation of a "mercury sorbent" by "treating a carbonaceous substrate [e.g., activated carbon sorbent] with an effective amount of a bromine-containing gas for a time sufficient to increase the ability of the carbonaceous substrate to adsorb mercury and mercury-containing compounds."[1337] As further confirmation that my analysis is correct, and that the bromine-containing gases in Nelson are promoters, I note that the '147 patent describes a promoter through which "activity for mercury capture is enhanced by the addition of halogen (e.g. bromine) to the carbon structure."[1338]

a. Particulate sorbent material comprising activated carbon

954. Nelson discloses the use of powdered activated carbon ("PAC"), in particulate form, as a sorbent material to capture mercury. Nelson describes in multiple places that the sorbent used is PAC:

[1336] Ex. 1012 (Nelson) at claims 19, 22.

[1337] Ex. 1012 (Nelson) at Abstract; *see also* Ex. 1012 (Nelson) at 4:58-63, 6:10-16, 7:33-36, claim 1.

[1338] Ex. 1001 ('147 Patent) at 13:22-25; *see also* State of the Art, above, § XII.G.2.

> There are five essential elements to the mercury sequestration claims of the present invention. The first three are that (1) a carbon-based adsorbent, such as powdered activated carbon (PAC), is used (2) to capture and concentrate vaporous mercury species from (3) a hot, flowing gas stream of combustion products.[1339]

Nelson exposes the "carbonaceous material, preferably powdered activated carbon (PAC), to gaseous bromine, Br_2(g), or to gaseous hydrogen bromide, HBr(g)."[1340] Each of Examples 1-8 of Nelson, including Example 1, use PAC as the sorbent.[1341] The use of PAC as the sorbent can also be seen in the captions and labels in Figs. 7-15,[1342] and in many of the claims of Nelson.[1343] The powdered activated carbon sorbent is further labeled in Fig. 1 as item 1 ("Carbonaceous Substrate material (e.g. PAC)," and after undergoing reaction with bromine, as "Improved Mercury Sorbent."[1344] Fig. 1 is excerpted below.

1339 Ex. 1012 (Nelson) at 5:63-6:1.

1340 Ex. 1012 (Nelson) at 6:10-15; *see also* 6:26-34; 7:10-13

1341 Ex. 1012 (Nelson) at 11:10-13 (Example 1), 12:9-14 (Comparative Example 1, Norit Darco® FGD PAC), 12:20-27 (Example 2, Norit Darco® FGD PAC), 13:10-12 (Example 3, Norit Darco® FGD PAC), 13:33-36 (Example 4), 13:59-63 (Example 5), 14:40-43 (Example 6), 15:24-27 (Example 7), 15:41-52 (testing leaching of the sorbents used in previous examples).

1342 Ex. 1012 (Nelson) at Figs. 7-15.

1343 Ex. 1012 (Nelson) at claims 3, 7, 10, 17, 22, and 26.

1344 Ex. 1012 (Nelson) at Fig. 1.



Nelson discloses several brands of "commercially-available powdered activated carbons (PACs)," and focuses on the PAC provided by Norit, because "Norit's Darco FGDO® is a common PAC frequently used by other researchers as a comparative yardstick."[1345]

955. Nelson describes that the activated carbon sorbent is in particulate form:

> Preferably the activated carbon is *in a very fine state,* which allows for a more uniform bromination later in the process. An example would be a *powdered* activated carbon (PAC).[1346]

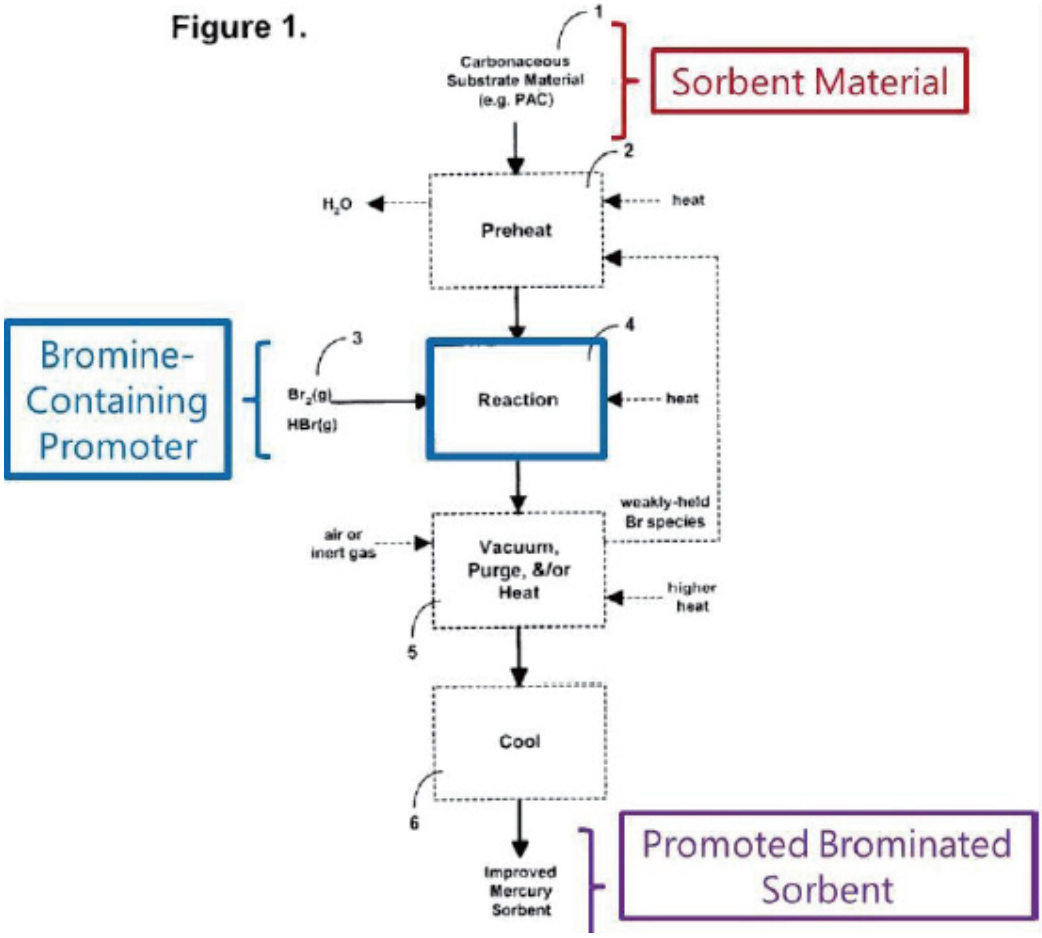
956. Nelson refers to the powdered activated carbon as containing "carbon particles" or "carbonaceous ... particles."[1347] Nelson describes the "particle size" in the claims, providing further disclosure of using activated carbon in particulate form.[1348]

b. **Promoting at least a portion of the sorbent material by chemically reacting the sorbent material with a bromine**

1345 Ex. 1012 (Nelson) at 11:11-20.
1346 Ex. 1012 (Nelson) at 7:31-34 (emphasis added).
1347 Ex. 1012 (Nelson) at 6:34-37, 7:16-18, 7:64-66.
1348 Ex. 1012 (Nelson) at claims 6, 8, 9, 11, 14-17, 25

containing promoter to form a promoted brominated sorbent,"

957. Nelson describes a process for promoting at least a portion of the particulate sorbent material (e.g., Norit Darco® FGD) by chemically reacting the PAC with a bromine containing promoter (e.g., Br_2(g) and/or HBr(g)) to form a promoted brominated sorbent. This can be seen in Fig. 1, which is annotated below.[1349]

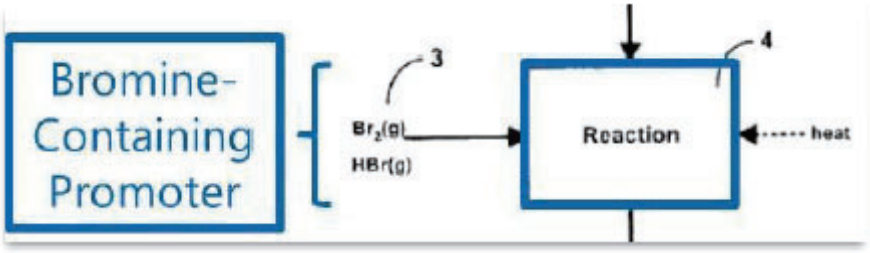


1349 Ex. 1012 (Nelson) at Fig. 1 (annotated).

The activated-carbon sorbent material (in red) is labeled "Carbonaceous Substrate Material (e.g. PAC)."[1350] Nelson describes that the carbonaceous substrate material can include "many different materials" including "activated carbon," and that activated carbon is the "preferred carbonaceous substrate material."[1351] The bromine-containing promoter (in blue) chemically reacts with the activated-carbon sorbent, as indicated by box 4 ("Reaction") to form a promoted brominated sorbent (purple, labeled "Improved Mercury Sorbent").

i The bromine-containing promoter chemically reacts with the activated carbon

958. Nelson describes that the activated carbon (shown in red in Fig. 1, above) is chemically reacted with a bromine-containing promoter. The bromine-containing promoter is injected in Step 3 in the form of elemental bromine gas (Br_2) and/or hydrogen bromide gas (HBr), shown in blue in Fig. 1. The bromine-containing promoter chemically reacts with the activated carbon sorbent in Step 4, labeled "Reaction."[1352]



1350 Ex. 1012 (Nelson) at Fig. 1, 7:4-5.
1351 Ex. 1012 (Nelson) at 7:6-9, 7:24-25, 7:31-33.
1352 Ex. 1021 (Nelson) at Fig. 1.

959. Nelson describes that upon contact between the bromine-containing promoter and activated carbon, a chemical reaction also takes place. In addition to labeling Step 4 "Reaction," Nelson states:

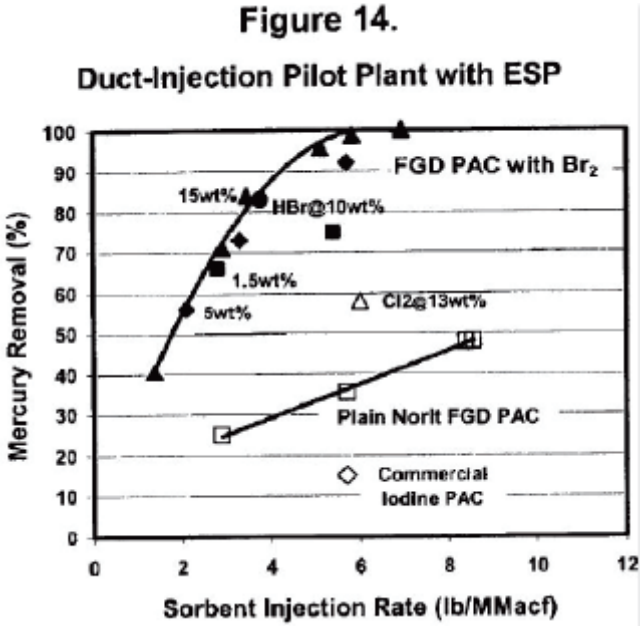
> A critical element in the process is that a bromine-containing gas 3 *is used to treat the carbonaceous substrate.* Preferably this gas comprises elemental bromine, Br_2 (g), although other bromine-containing gases, such as hydrogen bromide, HBr, will also have the advantageous effect of the invention.[1353]
>
> The key step in the sorbent manufacturing process is exposing the dried carbonaceous materials to the bromine-containing gas, 4. When the gas contacts the solids, *it is* quickly adsorbed *and reacted with materials*.[1354]
>
> *The carbonaceous materials will both physically adsorb the bromine species at 4 and chemically react with them.* It is preferable to minimize the amount of bromine that is physically-adsorbed weakly on the carbons. Physically-adsorbed bromine is prone to desorb from the materials upon changed conditions, such as injection into a hotter gas stream, for example. It is desirable to have the bromine as stable as possible on the carbon, yet in a form that is still reactive towards mercury.[1355]
>
> "[C]hlorine and bromine, which *chemically react* with strongly-held carbon surface compounds ...."[1356]
>
> "While not intending to be limited by hypothesized chemistry, it appears that in exposing PAC to concentrated bromine gas, *a relatively large quantity of the bromine reacts with the carbon*, forming surface compounds on the large surface-area of the carbon. When the PAC is then injected into the flue gas, the elemental mercury and oxidized mercury species there appear to

1353 Ex. 1012 (Nelson) at 7:45-51 (emphasis added).
1354 Ex. 1012 (Nelson) at 8:8-12 (emphasis added).
1355 Ex. 1012 (Nelson) at 8:21-30 (emphasis added).
1356 Ex. 1012 (Nelson) at 2:36-37 (emphasis added).

> react with at least one form of the bromine-carbon surface compounds that were created and are held fast.[1357]
>
> The size of the carbonaceous particles during bromination is not critical as long as their mass is uniformly exposed to *and reacted with* the bromine.[1358]
>
> *The elemental bromine was adsorbed and reacted with the PACs* much faster than was the elemental chlorine, for example—one-hundred-times faster.[1359]

960. When Nelson describes that elemental bromine "was adsorbed and reacted with the PACs," Nelson is referring to a promotion reaction. As I describe in the State of the Art, it was known that halogens (particularly chlorine-containing and bromine-containing species) reacted with activated carbon, and that the reaction was one of promotion of the activated carbon.[1360] For example, Nelson describes for Example 5, shown in Fig. 14, that the "brominated PAC achieved 90% mercury removal with only 4 lb of sorbent injected/MMacf" [million actual cubic feet] of flue gas.[1361]

1357 Ex. 1012 (Nelson) at 6:26-34 (emphasis added).
1358 Ex. 1012 (Nelson) at 7:16-19 (emphasis added).
1359 Ex. 1012 (Nelson) at 14:44-48 (emphasis added).
1360 *See* State of the Art, above, § § XII.C.3, XII.G.2.
1361 Ex. 1012 (Nelson) at 14:1-2, 14:12-14; Fig. 14.



At the same sorbent injection rate, the activated-carbon sorbent treated with bromine-containing species removed significantly more mercury than the "Plain Norit FGD PAC" (the untreated activated carbon).

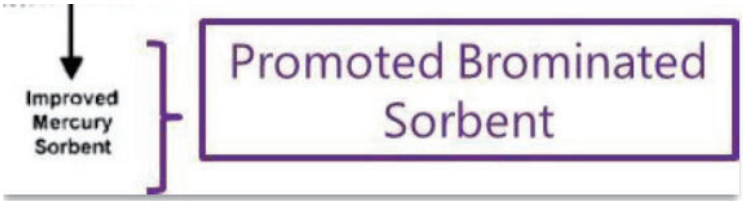
961. Olson-Paper proposes a model to explain the underlying basis for these results, as described below for Claim Elements 1(a)(3) and 1(a)(4). Olson-Paper explains that the "basic carbene [on untreated activated carbon] cannot react directly with Hg^0 [elemental mercury], but reacts with HCl to form stable carbenium ion intermediates, which are then ***active for binding*** Hg^0, accepting electrons from the atom (Figure 2). Thus HCl ***or other acids promote the oxidation step***."[1362]° Olson-Paper explains that elemental mercury has a low affinity for the basic sites on

1362 Ex. 1079 (Olson-Paper) at 981.

activated carbon, but that upon exposure to acid gases, the acid gases promote the sites on activated carbon and increase their affinity towards elemental mercury.

ii The bromine-containing promoter forms a promoted brominated sorbent.

962. Nelson describes that, as a result of the chemical reaction between the activated carbon sorbent and the bromine-containing promoter, a promoted brominated sorbent is formed. In Figure 1, Nelson labels the promoted brominated sorbent as "Improved Mercury Sorbent."[1363]



Nelson describes the "improved mercury sorbent" in multiple figures. Figure 1 shows a "block diagram of the process for manufacturing the improved mercury sorbent compositions," Figures 2-6 "describe "example methods for using the improved sorbent compositions," and Figures 7-9 show "performance plots indicating improvements in mercury capture with the invention."[1364]

963. Nelson further refers to the "improved mercury sorbent," formed from the chemical reaction between the activated carbon sorbent and the bromine-

1363 Ex. 1012 (Nelson) at Fig. 1 (annotated).

1364 Ex. 1012 (Nelson) at 5:28-36 (Brief Description of the Drawings).

containing promoter, as a "brominated mercury sorbent." This can be seen, for example, in claim 19 of Nelson.[1365]

> **19**. A process for manufacturing a mercury sorbent, comprising:
>
> providing a carbonaceous substrate;
>
> providing a bromine-containing gas; and
>
> contacting the carbonaceous substrate with the bromine-containing gas for a sufficient time to increase the mercury adsorbing ability of the carbonaceous substrate;
>
> to provide a brominated mercury sorbent capable of adsorbing mercury in a high temperature combustion gas.

964. Nelson describes that the bromine-containing species chemically reacts with the activated carbon and improves the effectiveness of the activated carbon in sequestering mercury compared to untreated activated carbon.[1366] For example, Figures 12 and 13 compare the ability of un-promoted activated carbon ("Norit Darco FGD," labeled "Untreated") in removing mercury, as compared to the activated carbon promoted with bromine.

1365 Ex. 1012 (Nelson) at claim 19.

1366 Ex. 1012 (Nelson) at Abstract; *see also* Ex. 1012 (Nelson) at 5:35-37, 6:10-16, 7:33-35, claim 1.

Figure 12.

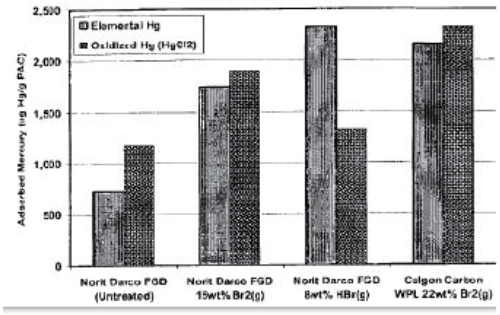
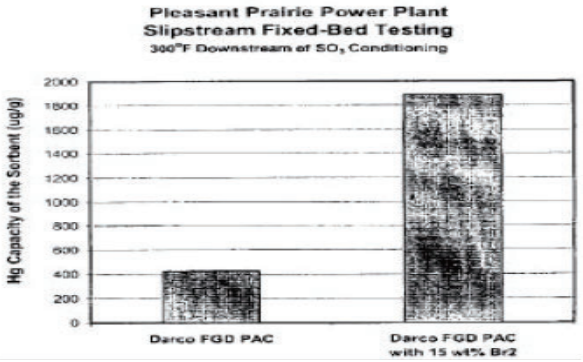


Figure 13.

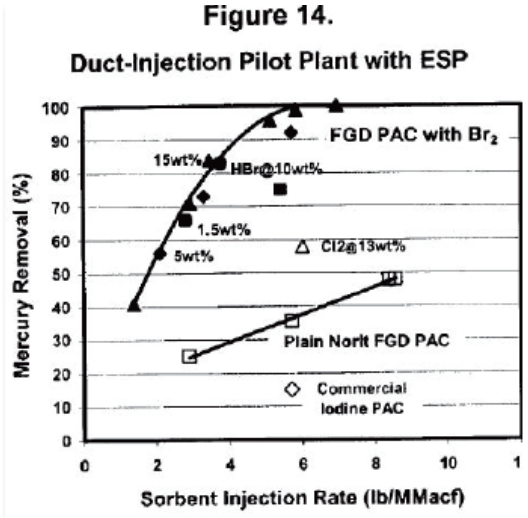


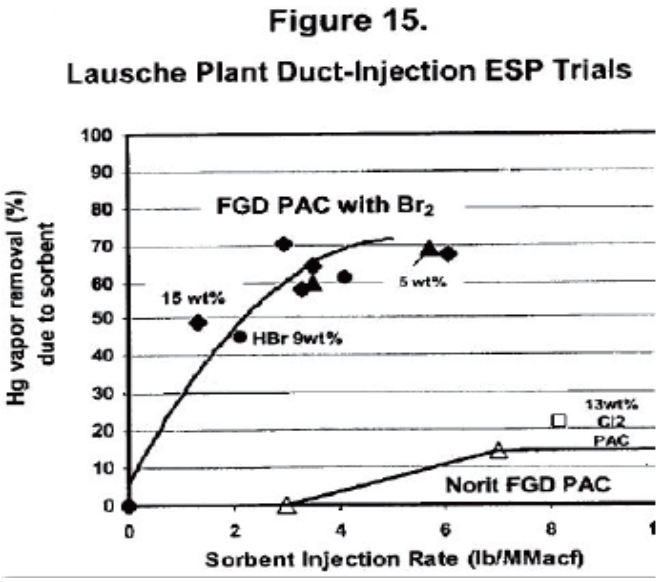
965. As shown in Figure 12, as a result of the bromine promotion in Nelson, "the brominated carbons adsorbed considerably more mercury species than the untreated versions, with the improvements averaging about 100%."[1367] As shown in Figure 13, "the brominated sorbent performed the best, removing over 300% more mercury than the untreated PAC, for example."[1368]

966. Other figures of Nelson further indicate that the injected bromine acts as a promoter. As compared to untreated PAC (labeled "Plain Norit FGD PAC"), the "improved mercury sorbent" of Nelson more efficiently removes mercury as compared to untreated activated-carbon sorbent.

1367 Ex. 1012 (Nelson) at 13:13-17.

1368 Ex. 1012 (Nelson) at 13:33-35.





Figures 14 and 15 show close to 100% overall mercury removal with bromine-treated PAC (Figure 14)[1369] and more than 70% mercury removal on the sorbent itself with bromine-treated PAC (Figure 15).[1370]

3. Claim 1: Element 1(a)(2) — "whrerin the bromine containing promoter is in gaseous form, vapor form, or non-aqueous liquid form."

967. This limitation is disclosed by Nelson. Nelson describes in multiple places that the bromine-containing promoter is in gaseous form, vapor form, or non-aqueous liquid form. In particular, Nelson describes promoting the activated carbon using hydrogen bromide (HBr) and/or molecular bromine (Br_2), each in gaseous form:

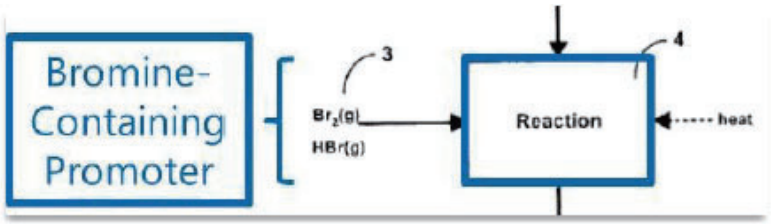
1369 Ex. 1012 (Nelson) at Fig. 14, 14:1-14.
1370 Ex. 1012 (Nelson) at Fig. 15, 15:5-40.

In some aspects of this manufacture, the carbonaceous substrate is activated carbon. In some aspects of the manufacture, the bromine-containing *gas comprises elemental bromine (Br_2) and/or hydrogen bromide (HBr).*[1371]

In some aspects of the invention, the bromine-containing gas comprises at least one of: elemental bromine and hydrogen bromide. In some aspects of the invention, the carbonaceous substrate comprises activated carbon.[1372]

Elemental bromine is a liquid at ambient temperature, but turns to a gas at only a modestly elevated temperature. Hydrogen bromide is a gas at even ambient temperature. Using a gas-phase carbon reactant considerably simplifies the production of the sorbent and leads to the low costs which are a requirement for a sorbent to be used as a once-through duct injectant.[1373]

A critical element in the process is that a bromine-containing gas 3 is used to treat the carbonaceous substrate. Preferably this gas comprises elemental bromine, Br_2 (g), although other bromine-containing gases, such as hydrogen bromide, HBr, will also have the advantageous effect of the invention.[1374]



1371 Ex. 1012 (Nelson) at 5:18-21 (emphasis added).
1372 Ex. 1012 (Nelson) at 4:64-67.
1373 Ex. 1012 (Nelson) at 6:46-52.
1374 Ex. 1012 (Nelson) at 7:45-51.

Nelson demonstrates in Figure 1 that the bromine-containing promoter is in the gas phase (denoted by "(g)") when it contacts and chemically reacts with the activated carbon.[1375]

968. The claims of Nelson repeatedly recite that the bromine-containing promoter is in gaseous form. Claim 1 of Nelson is highlighted below:[1376]

1. A method for removing mercury and mercury-containing compounds from a combustion gas in an exhaust gas system, comprising the steps of:
providing a mercury sorbent that has been prepared by treating a carbonaceous substrate with an effective amount of a bromine-containing gas for a sufficient time to increase the ability of the carbonaceous substrate to adsorb mercury and mercury-containing compounds;
injecting the mercury sorbent into a stream of the mercury-containing combustion gas for a sufficient time to allow an effective amount of the mercury and mercury-containing compounds in the combustion gas to adsorb onto the mercury sorbent; and
collecting and removing the mercury sorbent from the combustion gas stream.

Other claims also recite that the bromine promoter is in gaseous form.[1377]

4. Claim 1: Element 1(a)(3) — "and wherein the activated carbon contains graphene sheets having carbene species edge sites"

1375 Ex. 1012 (Nelson) at Fig. 1.

1376 Ex. 1012 (Nelson) at claim 1.

1377 Ex. 1012 (Nelson) at claim 19 ("providing a bromine-containing gas"); Claims 2, 17, 20, 26 ("the bromine-containing gas comprises elemental bromine"); Claim 6, 21 ("the bromine-containing gas comprises hydrogen bromide").

969. This limitation is disclosed by Olson-Paper, and obvious over Nelson in view of Olson-Paper. As discussed above regarding the State of the Art,[1378] it was proposed since at least the 1980s that activated carbon (at least in a clean laboratory setting) has graphene sheets having carbene species edge sites. Thus, the inventors of the '147 patent were just describing a property of graphene that had been theorized decades earlier to those of skill in the art.

970. Olson-Paper applies these known teachings of the surface structure of activated carbon. Olson-Paper supplements the teachings of Nelson by identifying surface compounds formed in the activated carbon of Nelson, and proposing chemical reaction mechanisms underlying Nelson. In addition to the discussion above in the Reasons to Combine section, a person of skill in the art would have had a reasonable expectation of success combining Nelson with Olson-Paper because no modifications would need to have been made to the process conditions, chemical reactors, activated carbon sorbent, or halogen promoter used in Nelson. Olson-Paper merely seeks to describe the chemistry already taking place in Nelson.

971. Nelson describes his invention using the commercially-available, powdered-activated carbon provided by Norit, because "Norit's Darco FGD® is a common PAC frequently used by other researchers as a comparative yardstick."[1379]

1378 *See* State of the Art, above, § XII.C.2.

1379 Ex. 1012 (Nelson) at 11:17-20.

Indeed, Figures 9-15 of Nelson expressly reference Norit Darco FGD activated carbon in either the title or caption.[1380] Olson-Paper describes the surface structure of this brand of activated carbon, referring to it as "Norit FGD."[1381] Olson-Paper studied the surface structure of "two AC [activated carbon] sorbents, Norit FGD and the EERC lignite-derived AC, exposed to various simulated flue gas compositions."[1382] The same brand name of activated carbon—Norit FGD—was studied in both Nelson and in Olson-Paper. A person of skill in the art would have applied the teachings of Olson-Paper to the activated carbon in Nelson.

972. Both Nelson and Olson-Paper describe the effects when Norit Darco FGD is exposed to halogens. Nelson describes that exposing activated carbon to chlorine and bromine improves the effectiveness in mercury removal, although bromine works better.[1383] Nelson further explains that the reactions occur on the "surface" of activated carbon, stating that "a relatively large quantity of the bromine reacts with the carbon, forming surface compounds on the large surface-area of the carbon."[1384] Olson-Paper describes such surface compounds and models for chemical

1380 Ex. 1012 (Nelson) at Figs. 9-15.
1381 Ex. 1079 (Olson-Paper) at 981.
1382 Ex. 1079 (Olson-Paper) at 981.
1383 Ex. 1012 (Nelson) at 6:15-19, 12:28-30, 14:16-19, Fig. 11, Fig. 14.
1384 Ex. 1012(Nelson) at 6:26-30.

reaction pathways between halogens and the surface of the Norit Darco FGD® activated carbon.[1385]

973. Olson-Paper proposes that activated carbon, particularly the Norit Darco FGD® disclosed in Nelson, contains graphene sheets having carbene species edge sites. Olson-Paper states in the Abstract that his model describes "a zig-zag *carbene site on the carbon edge* that performs as a Lewis base."[1386] The "carbon edge" refers to the edge sites on graphene, which contains the carbene species. Olson-Paper elaborates regarding the "carbene structures" present "at the edges of the carbon graphene layers" in activated carbon:[1387]

> A refinement of the mechanistic model for Hg^0 oxidation and binding is now proposed that offers more detail on the nature of the carbon site and its interaction with flue gases and Hg. This model uses the concept of *zig-zag carbene structures recently proposed for electronic states at the edges of the carbon graphene layers* [8]. *In the edge carbene model of Hg capture, the zig-zag carbon atom positioned between aromatic rings is hypothesized to be a Lewis base site.* The basic carbene cannot react directly with Hg^0, but reacts with HCl to form stable carbenium ion intermediates, which are then active for binding Hg^0, accepting electrons from the atom (Figure 2). Thus HCl or other acids promote the oxidization step.

974. Reference 8 refers to the paper by Radovic, a previous researcher who had already investigated "the surface chemistry of edge carbon atoms" in graphene

1385 Ex. 1079 (Olson-Paper) at 979 (Abstract).
1386 Ex. 1079 (Olson-Paper) at 979 (Abstract) (emphasis added).
1387 Ex. 1079 (Olson-Paper) at 982 (emphasis added).

layers and "argue[d] in favor of" "carbene or m-benzyne at the zigzag sites."[1388] A person of skill in the art would have recognized that "graphene layers" described by Olson-Paper is another word for "graphene sheets." The graphene sheets are shown in Fig. 2 of Olson-Paper, and the carbene species edge site is labeled by Olson-Paper as "Carbon Basic Zig-Zag Site."[1389]

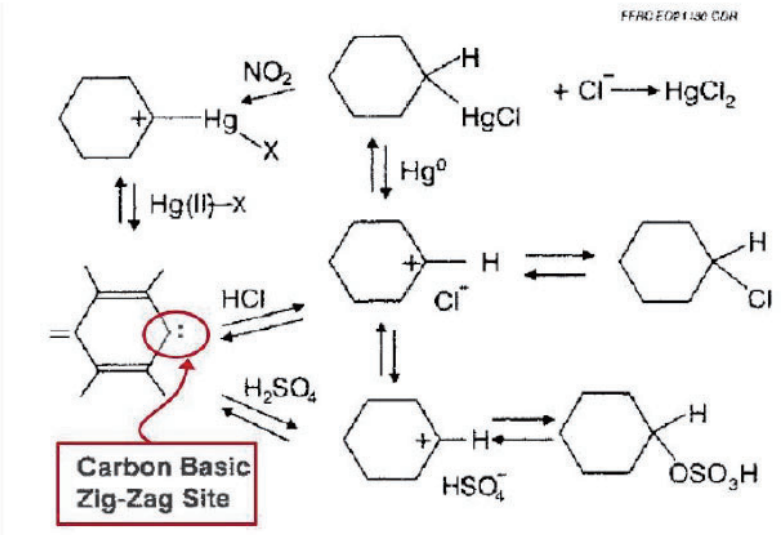


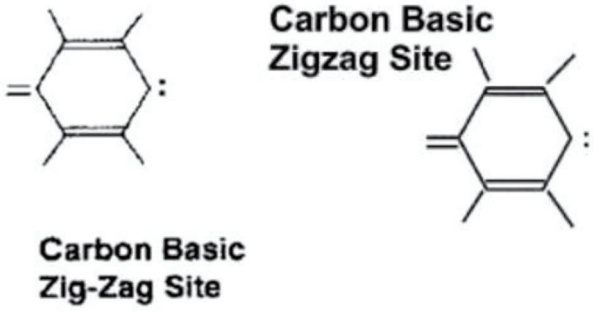
Figure 2. Reaction site model for activated carbon.

975. As I describe in the State of the Art section,[1390] a person of skill in the art would have known that each vertex represents a carbon atom, and each hexagon represents an aromatic ring. A POSITA would have further known that graphene is a structure having sheets of such aromatic ring systems stacked in layers upon one

1388 Ex. 1046 (Radovic); See State of the Art, above, § XII.G.2.
1389 Ex. 1079 (Olson-Paper) at 982.
1390 *See* State of the Art, above, § XII.A.5.

another.[1391] Further, the "Lewis base site" described on page 982 by Olson-Paper means a site that can donate electrons.[1392] The zig-zag carbon atom, circled in red above from Figure 2 in Olson-Paper, is a "carbene species edge site," as per claim 1 of the '147 patent, because it contains a neutral carbon atom that is bonded to two other carbon atoms and that has two unshared valence electrons (i.e., a lone pair or dangling pair of electrons that it can donate when performing chemical reactions).

976. As further confirmation that my analysis of the disclosure of Olson-Paper is correct, I note that the depiction of a carbene species on a graphene sheet is nearly identical between the Olson-Paper (left)[1393] and '147 patent (right) .[1394]



And similar to both Nelson and Olson-Paper, the '147 patent also uses Norit Darco FGDO as the activated carbon sorbent of choice.[1395] This is because, as described by

[1391] *See* State of the Art, above, § § XII.A.5, XII.C.2; Ex. 1070 (Bansal) at 238.
[1392] Ex. 1079 (Olson-Paper) at 982.
[1393] Ex. 1079 (Olson-Paper) at 982, Fig. 2.
[1394] Ex. 1001 ('147 Patent) at Fig. 2.
[1395] Ex. 1001 ('147 Patent) at 5:52-67 (describing Figs. 4-9), 14:40-46, 15:46, 20:48.

Nelson, "Norit's Darco FGD® is a common PAC frequently used by other researchers as a comparative yardstick."[1396]

5. Claim 1: Element 1(a)(4) — "which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury;"

977. This limitation is disclosed by Olson-Paper, and is obvious over Nelson in view of Olson-Paper. As I discuss above regarding Claim Element 1(a)(1), Nelson describes that the activated carbon chemically reacts with the bromine containing promoter. Olson-Paper teaches the mechanism by which the reaction takes place, namely, an acid gas (e.g., HBr or HCl) reacts with the activated carbon (e.g., Norit Darco FGD) to form a carbocation paired with an anion (e.g., the Cl^- or the Br^- from the acid gas) in the promoted brominated sorbent.[1397] The resulting promoted brominated sorbent described in Nelson is employed for the purpose of oxidation and capture of mercury.

978. Olson-Paper describes that activated carbon, particularly the Norit Darco FGD® disclosed in Nelson, undergoes the following reactions for purposes of oxidation of elemental mercury:

> *A refinement of the mechanistic model for Hg^0 oxidation* and binding is now proposed that offers more detail on the nature of the carbon site and its interaction with flue gases and Hg. *This model uses the concept of zig-zag carbene structures recently*

1396 Ex. 1012 (Nelson) at 11:17-20.

1397 Ex. 1079 (Olson-Paper) at 979-82.

> *proposed for electronic states at the edges of the carbon graphene layers* [8]. In the edge carbene model of Hg capture, the zig-zag carbon atom positioned between aromatic rings is hypothesized to be a Lewis base site. *The basic carbene cannot react directly with Hg^0, but reacts with HCl to form stable carbenium ion intermediates, which are then active for binding Hg^0, accepting electrons from the atom (Figure 2). Thus HCl or other acids promote the oxidation step*.[1398]

979. In the above passage, Hg^0 refers to elemental mercury (i.e., non-oxidized mercury, with an oxidation state of 0). A person of skill in the art would have recognized that the "carbenium ion intermediates" disclosed in Olson-Paper is another term for a "carbocation." Olson-Paper identifies this carbenium ion intermediate, or carbocation, as responsible for oxidizing mercury—"promote the oxidation step," as described by Olson-Paper. Below is an annotated Figure 2 from Olson-Paper, showing formation of a carbocation (step 1) and oxidation and capture of elemental mercury (step 2):[1399]

[1398] Ex. 1079 (Olson-Paper) at 982 (emphasis added).

[1399] Ex. 1079 (Olson-Paper) at 982, Fig. 2.

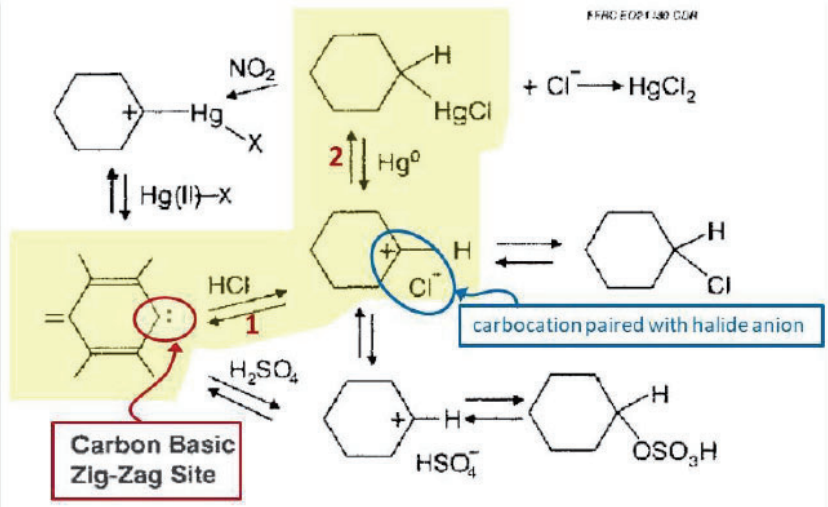


Figure 2. Reaction site model for activated carbon.

980. As can be seen in the above figure, annotated from Olson-Paper, a halogen-containing promoter (e.g., a hydrohalide, HCl), chemically reacts in step 1 with the carbene species (circled in red) at the edge site of a graphene layer (which contains a sheet of such hexagon rings). The result of step 1, circled in blue, is formation of a carbocation (indicated by the +) paired with a halide anion (indicated by the (Cl^-). The carbon circled in blue (indicated by a vertex with a +) is a carbocation, because the carbon atom only has 3 bonds to neighboring elements (2 bonds to other carbon atoms, and 1 bond to hydrogen), and thus six electrons in its valence shell. As shown in step 2, the carbocation paired with the halide anion in the promoted halogenated sorbent is for oxidation of the mercury. Elemental mercury (indicated by Hg^0) is oxidized in step 2 to Hg(II) or Hg^{2+}—since the elemental mercury gives up electrons and thus gains a positive formal charge—as evidenced by the bonding of the mercury to both the adjacent carbon and the halogen atom (Cl).

This bonding configuration between Hg^{2+} and Cl is consistent with the XAFS spectra discussed above.[1400]

981. Although the example in Olson-Paper expressly identifies hydrochloric acid (HCl) and chloride anions (Cl^-), a person of skill in the art would have recognized that Nelson in view of Olson-Paper teaches the same mechanism for a bromine-containing promoter, such as HBr. First, Olson-Paper states that the mechanism is not limited to HCl, but is valid for "HCl or other acids."[1401] A POSITA, in view of Nelson, would have recognized that such other acids would have included HBr, especially since the bond dissociation energy for HBr is lower than that for HCl.[1402] Indeed, Fig. 2 of Olson-Paper uses "—X" in the figure to indicate that model is not limited to a chloride anion, but could include other anions. Nelson describes HBr as one such exemplary promoter throughout the reference.[1403]

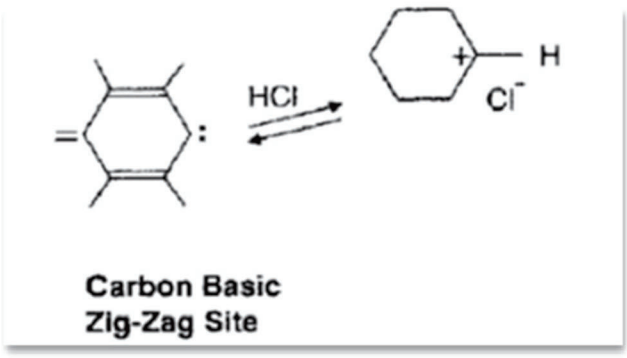
982. A POSITA would have been further motivated to combine with Olson-Paper to propose a model for the reaction chemistry taking place in Nelson, since both references teach using a halogen with activated carbon to promote capture of both elemental and oxidized mercury. Nelson expressly discloses using a bromine promoter, in which both "the elemental mercury and oxidized mercury species there

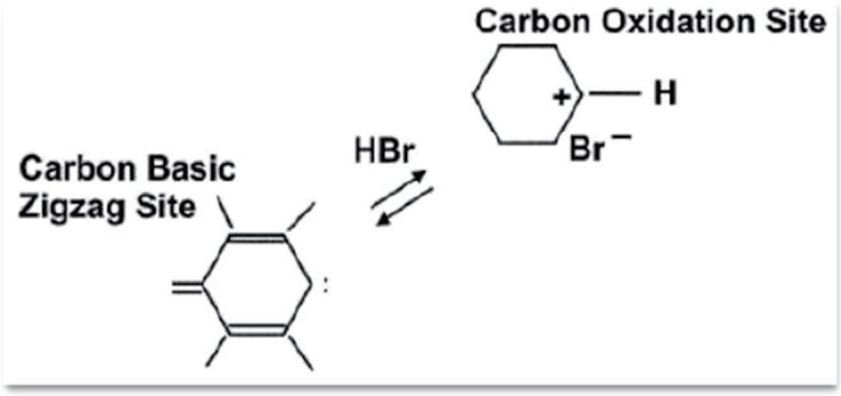
1400 *See* State of the Art, above, § XII.C.4.
1401 Ex. 1079 (Olson-Paper) at 982.
1402 *See* State of the Art, above, § XII.G.2.
1403 *See, e.g.,* Ex. 1012 (Nelson) at 6:10-15, 7:45-51, Fig. 1.

appear to react with at least one form of the bromine-carbon surface compounds."[1404] Olson-Paper expressly discloses capture of elemental mercury and oxidized mercury.[1405] A person of skill in the art would have expected that when using the same brand-name of activated carbon in both Nelson and Olson-Paper (Norit Darco FGD), that bromine and halogen would follow similar reaction and oxidation pathways with activated carbon. Indeed, both chlorine and bromine are in the halogen family, both are well-known oxidizing agents, and both have similar chemical properties.[1406]

983. As further confirmation that my analysis of the disclosure of Olson-Paper is correct, I note that the depiction of the reaction mechanism is nearly identical between Olson-Paper (top)[1407] and the '147 patent (bottom).[1408] In both figures, the carbocation (indicated by the +) is paired with the halide anion.

1404 Ex. 1012 (Nelson) at 6:30-34.
1405 Ex. 1079 (Olson-Paper) at 979, Fig. 2.
1406 State of the Art, above, § § XII.A.1, XII.A.7, XII.C.3, XII.G.2.
1407 Ex. 1079 (Olson-Paper) at 982, Fig. 2.
1408 Ex. 1001 ('147 Patent) at Fig. 2.





984. And similar to both Nelson and Olson-Paper, the '147 patent also uses Norit Darco FGD® as the activated carbon sorbent of choice.[1409] This is because, as described by Nelson, "Norit's Darco FGD® is a common PAC frequently used by other researchers as a comparative yardstick."[1410]

[1409] Ex. 1001 ('147 Patent) at 5:52-67 (describing Figs. 4-9), 14:40-46, 15:46, 20:48.

[1410] Ex. 1012 (Nelson) at 11:17-20.

6. Claim 1: Element 1(b) — "chemically reacting elemental mercury in the mercury containing gas with the promoted brominated sorbent to form a mercury/sorbent chemical composition; and"

985. This limitation is disclosed by Nelson. This limitation is also obvious over Nelson in view of Olson-Paper. Nelson describes that the elemental mercury in the mercury-containing gas chemically reacts with the promoted brominated sorbent to form a mercury/sorbent chemical composition:

> While not intending to be limited by hypothesized chemistry, it appears that in exposing PAC to concentrated bromine gas, a relatively large quantity of the bromine reacts with the carbon, forming surface compounds on the large surface-area of the carbon. *When the PAC is then injected into the flue gas, the elemental mercury* and oxidized mercury species *there appear to react with at least one form of the bromine-carbon surface compounds that were created and are held fast.* When the carbon particles are removed from the flue gas along with the fly ash by the electrostatic precipitator (ESP) or fabric filter, the mercury is removed with them. The mercury sorbents are then disposed of with the fly ash. *Because the mercury has been chemically adsorbed, rather than just physically adsorbed*, the captured mercury appears to be very stable and does not revolatilize or leach.[1411]
>
> Mixing with the flue gas, the sorbent adsorbs its elemental mercury and oxidized mercury species.[1412]

986. The figures of Nelson further quantify how the elemental mercury reacts with the promoted brominated sorbent. For example, each of Figures 7-11 of Nelson plot the fractional removal of *elemental* mercury, as the labels of the y-axis in each

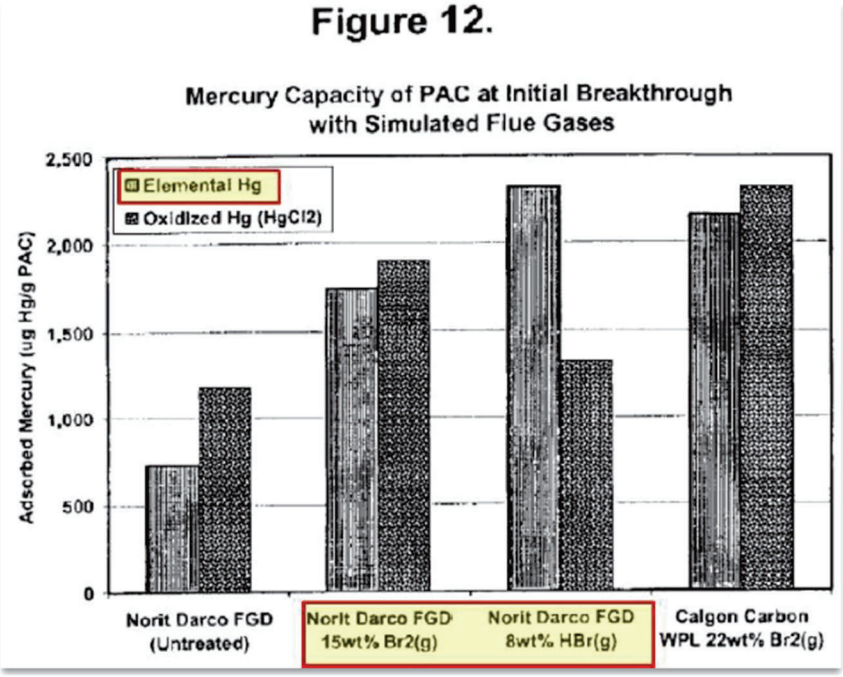
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1411 Ex. 1012 (Nelson) at 6:26-41 (emphasis added).

1412 Ex. 1012 (Nelson) at 9:35-37.

figure are "Hg(0) Fractional Removal."[1413] The "Hg(0)" refers to elemental mercury. Nelson further describes that Figure 11 plots "the comparative *elemental mercury* performance of a sorbent with this invention with those of other halogen treatments," and Figure 12 "presents the comparative capacity increases for both oxidized mercury ($HgCl_2$) and *elemental* mercury of three sorbents processed according to this invention."[1414] Figure 12 of Nelson, copied below, indicates that elemental mercury is chemically reacting with Norit Darco FGD activated carbon promoted by Br_2(g), and Norit Darco FGD promoted by HBr(g).[1415]

Figure 12.



1413 Ex. 1012 (Nelson) at Figs. 7-11.

1414 Ex. 1012 (Nelson) at 5:40-46 (emphasis added).

1415 Ex. 1012 (Nelson) at Fig. 12 (annotated); *see also* Figs. 14-15.

987. In addition to the express disclosures in Nelson, Nelson in view of Olson-Paper further reinforces to a POSITA that elemental mercury in the mercury containing gas reacts with the promoted brominated sorbent to form a mercury/sorbent chemical composition. Olson-Paper states that activated carbon, particularly the Norit Darco FGD® disclosed in Nelson, undergoes the following reactions for purposes of oxidation of elemental mercury:

> The basic carbene cannot react directly with Hg^0, but reacts with HCl to form stable carbenium ion intermediates, which are then active for binding Hg^0, accepting electrons from the atom (Figure 2). Thus HCl or other acids promote the oxidation step.[1416]

988. In the above passage, Hg^0 refers to elemental mercury (i.e., non-oxidized mercury). Below is an annotated Fig. 2 from Olson-Paper, showing in step 2 the reaction between the promoted halogenated sorbent and elemental mercury (Hg^0) to form a mercury/sorbent chemical composition:[1417]

[1416] Ex. 1079 (Olson-Paper) at 982.

[1417] Ex. 1079 (Olson-Paper) at 982, Fig. 2 (annotated).

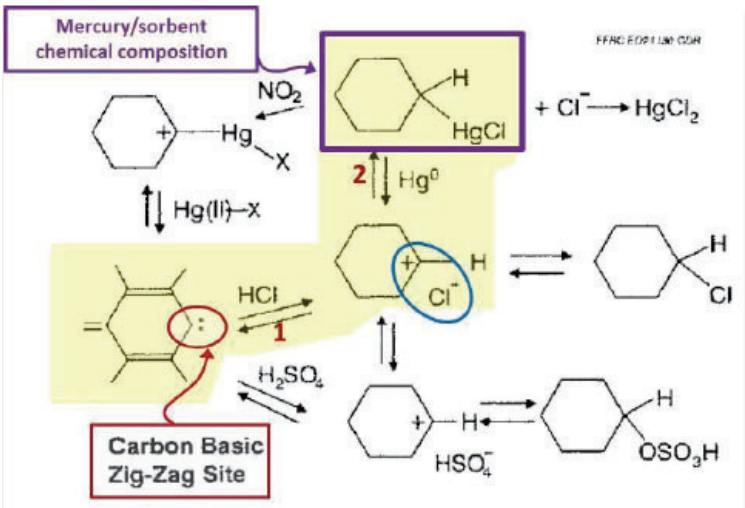


Figure 2. Reaction site model for activated carbon.

7. Claim 1: Element 1(c) —"separating particulates from the mercury containing gas, the particulates including ash and the mercury/sorbent chemical composition."

989. This limitation is disclosed by Nelson. Nelson discloses separating particulates from the mercury containing gas using, for example, a fabric filter and an electrostatic precipitator (ESP). Nelson states that the "adsorbent material [is] injected into the flowing gas [i.e., the mercury containing gas], intimately mix[es] with it, and [is] separated from the gas in a particulate collector."[1418] Nelson describes that the removal of particulates includes both fly ash and the mercury/sorbent chemical composition:

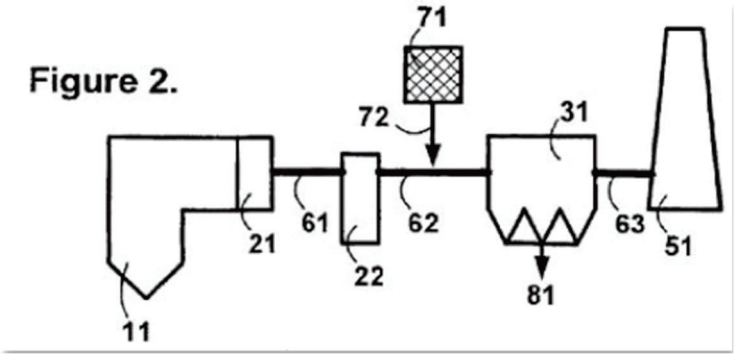
> When the carbon particles are removed from the flue gas along with the fly ash by the electrostatic precipitator (ESP) or fabric filter, the mercury is removed with them. The mercury sorbents are then disposed of with the fly ash. Because the mercury has been chemically adsorbed, rather than just physically adsorbed,

[1418] Ex. 1012 (Nelson) at 6:2-4.

> the captured mercury appears to be very stable and does not revolatilize or leach.[1419]
>
> FIGS. 2 through 6 are schematic diagrams of exhaust gas systems describing example methods for using the sorbents of the invention *to remove and sequester mercury* from hot combustion gases.[1420]

990. Each of Figures 2-4 and 6 individually disclose separating the mercury-sorbent composition and fly ash from the flue gas.1421

991. "FIG. 2 applies the sorbents to a combustion gas stream where a fabric filter (baghouse) is utilized to collect the fly ash generated during combustion. … Mixing with the flue gas, the sorbent absorbs its elemental mercury and oxidized mercury species. The sorbent flows with flue gas to a fabric filter 31 and is deposited on the filter bags in a filter cake along with the fly ash and other gas-stream particulates."[1422]



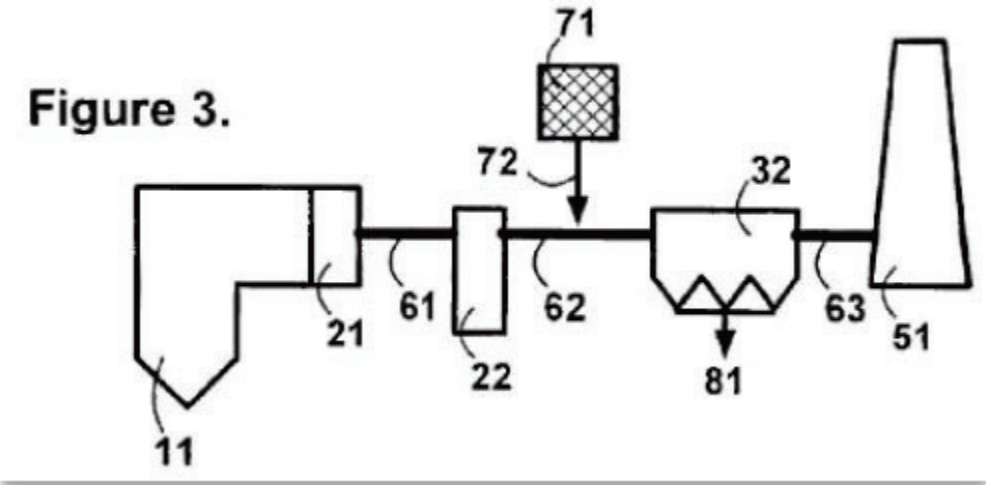
1419 Ex. 1012 (Nelson) at 6:30-41.

1420 Ex. 1012 (Nelson) at 9:17-20 (emphasis added).

1421 Ex. 1012 (Nelson) at Figs. 2-6. Fig. 5 has the fly ash separated before the sorbent is injected, using a "TOXECON®" arrangement. Ex. 1012 (Nelson) at 10:49-61.

1422 Ex. 1012 (Nelson) at 9:22-38 (describing Fig. 2).

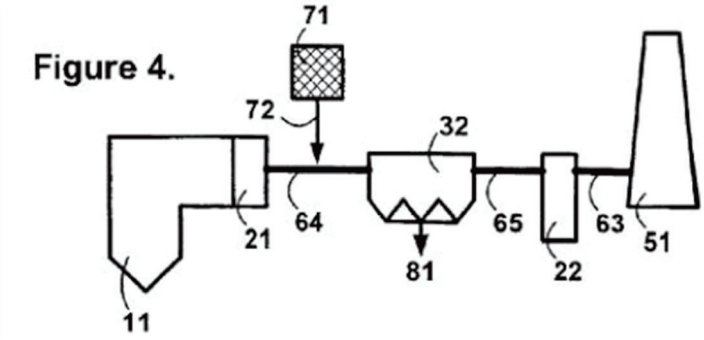
992. Figure 3 depicts the separation of mercury from flue gas in plants that have an "electrostatic precipitator (ESP) 32 instead of a fabric filter. … In the ESP 32, the sorbents are collected on plates with the fly ash and upon rapping of the plates are eventually discharged 81 from the ESP 32 for disposal along with the rest of the particulates."[1423]



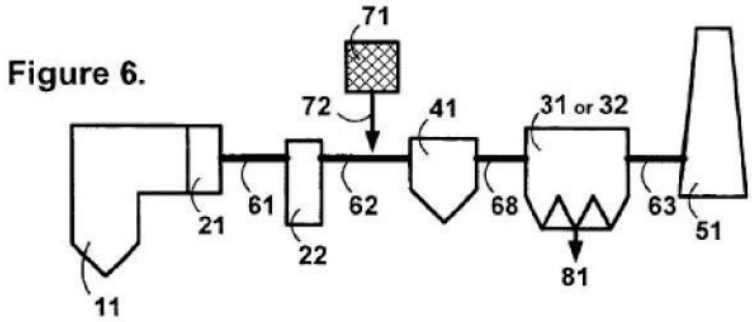
993. Figure 4 describes separating mercury from flue gas in plants with a "hot-side" ESP, in which "the air preheater 22 follows the ESP 32. … The sorbents would be collected with the other gas stream particulates in the hot-side ESP 32 and the cleaned gas would proceed through ductwork 65 to the smokestack."[1424]

1423 Ex. 1012 (Nelson) at 9:55-56, 10:4-8 (describing Fig. 3).

1424 Ex. 1012 (Nelson) at 10:9-26 (describing Fig. 4).



994. Figure 6 depicts separating mercury from the flue gas in plants equipped with a spray dryer.[1425] Nelson describes flexibility in that the sorbent can be injected before the spray dryer 41, into the spray dryer, into the ductwork 68, between the spray dryer and the particulate collector 31 or 32, or mixed within the scrubber slurry.[1426]



995. I also note that the '147 patent admits that particulate separators, including electrostatic precipitators were known in the art:

> By way of illustration and not limitation, particulate separator 140 may comprise one or more fabric filters, one or more

1425 Ex. 1020 (Nelson) at Fig. 6.

1426 Ex. 1020 (Nelson) at 10:62-67 (describing Fig. 6).

electrostatic precipitators (hereinafter "ESP"), or other particulate removal devices *as are known in the art.*[1427]

B. Dependent Claims

1. Claim 17

a. **Claim 17: Element 17(a)—"A method according to claim 1, "further comprising injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into a gas stream"**

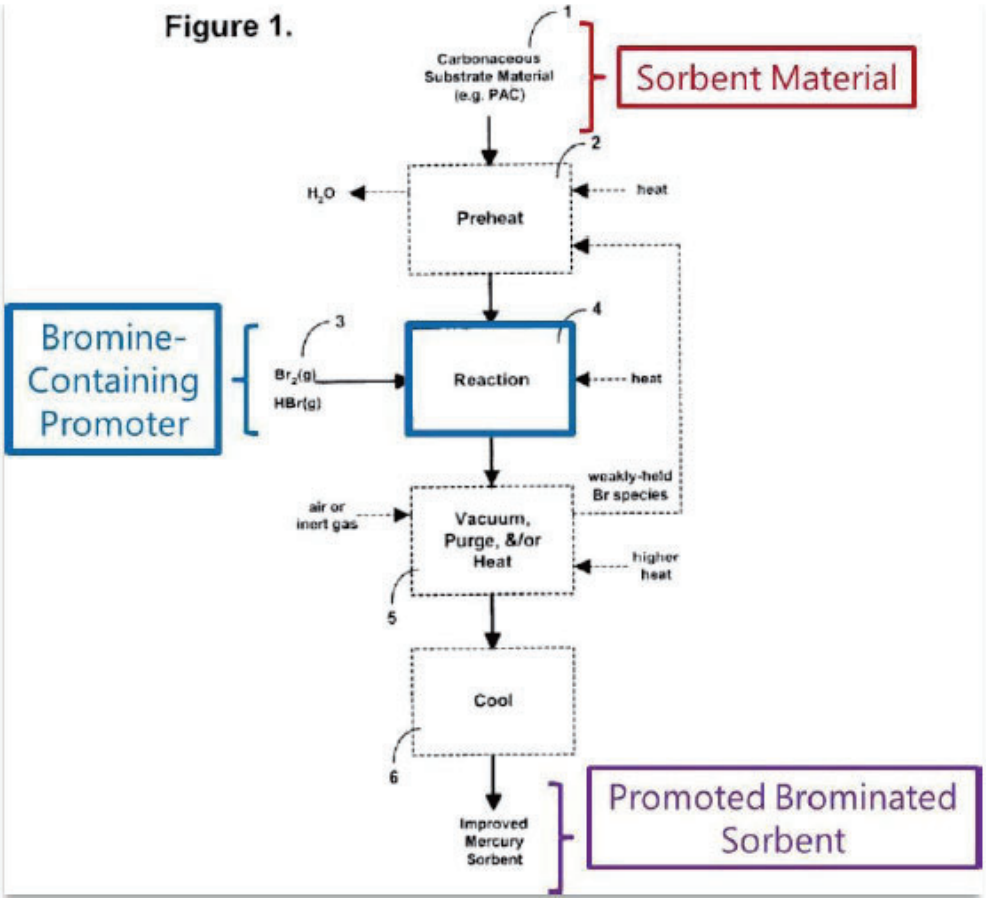
b. **Claim 17: Element 17(b)—"whereby in-flight reaction produces the promoted brominated sorbent,"**

c. **Claim 17: Element 17(c)—"wherein the promoter is reacted in the gas phase or as a vapor,"**

996. These limitations are disclosed by Nelson. The particulate sorbent material (powdered activated carbon) is discussed above for Claim Element 1(a)(1). Nelson shows in Figure 1 that the sorbent material (circled in red) and bromine-containing promoter are injected separately into a gas stream, in which in-flight reaction (circled in blue) produces the promoted brominated sorbent:[1428]

1427 Ex. 1001 ('147 Patent) at 8:61-66 (emphasis added).

1428 Ex. 1012 (Nelson) at Fig. 1 (annotated).



A POSITA would have understood that for sorbent and promoter to be injected, they must necessarily have been injected at an injection rate. For example, Figures 14 and 15 of Nelson refer to a "Sorbent Injection Rate."[1429]

997. As I discuss for Claim Element 1(a)(2) and also for Claim Element 1(a)(4), the in-flight reaction between a bromine-containing promoter in the gas phase and the powdered activated carbon produces the promoted brominated sorbent (shown in purple). Nelson describes that when the "bromine-containing gas, [step] 4

[1429] Ex. 1012 (Nelson) at Figs. 14-15.

... contacts the [PAC] solids, it is quickly adsorbed *and reacted with* materials."[1430] I note that nothing in claim 17 (or claim 1) of the '147 patent limits the claim to an in-flight reaction that occurs at the combustion site.

998. As shown in Figure 1 and described by Nelson, the bromine-containing promoter—Br_2(g) and/or HBr(g)—is a gas and that this gas is injected into another gas stream.[1431] For example, a carrier gas stream is used to transport the bromine-containing promoter: it may be beneficial to utilize a *diluting carrier gas to better distribute* the Br_2(g) or HBr(g) among the carbonaceous substrate particles."[1432] A POSITA would have recognized that this means the promoter is added to a carrier gas, and that the PAC (carbonaceous substrate) is added to this carrier gas. Nelson also explains that "any bromine species that are desorbed can be transported to unsaturated substrate materials [i.e., activated carbon] upstream in the process, eliminating the need to dispose of the off-gas stream."[1433]A person of skill in the art would have recognized that when a "desorbed species" is "transported," that refers to movement in a gas mixture. Nelson states that the powdered activated sorbent "is reduced to a particle size distribution fluidizable in the combustion gas stream prior

[1430] Ex. 1012 (Nelson) at 8:9-12 (describing Step 4 of Fig. 1) (emphasis added).
[1431] Ex. 1012 (Nelson) at 6:42-52.
[1432] Ex. 1012 (Nelson) at 7:64-66 (emphasis added).
[1433] Ex. 1012 (Nelson) at 9:9-12.

to the injecting step."[1434] The "fluidizable" refers to being transported in gas-phase in "ductwork,"[1435] meaning in a transport gas.

999. I note that the '147 patent employs a similar setup for transporting the promoter and activated-carbon sorbent, using "transport gas(es)" (purple) for the purpose of "entraining materials discharged from reservoirs" containing activated carbon (item 110, red), halogen promoter (item 120, blue), and secondary component (item 130, brown).[1436] Fig. 3 of the '147 patent is annotated below:

[1434] Ex. 1012 (Nelson) at 5:4-6; see also Ex. 1012 (Nelson) at claims 4, 5, 8, 9, 11, 14-17, 25.

[1435] Ex. 1012 (Nelson) at 6:22, 9:30-33, 9:60-66, 13:59-63, 14:23-26, 15:18-19, claim 25.

[1436] Ex. 1001 ('147 Patent) at 8:25-53, Fig. 3.

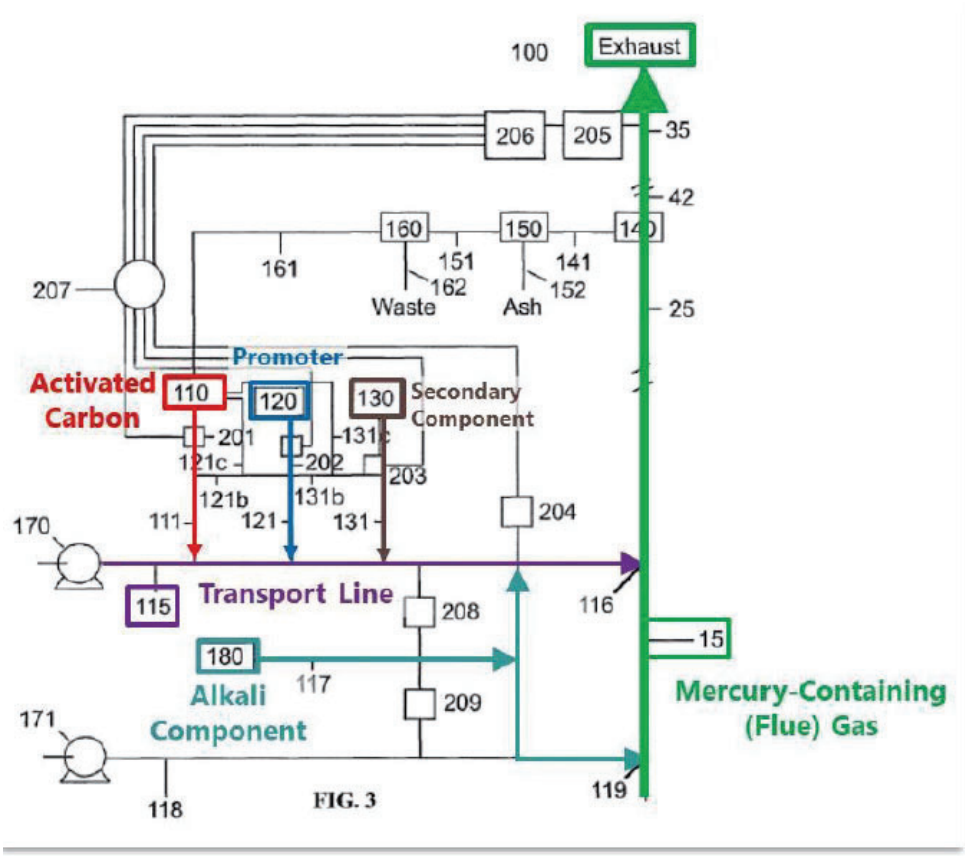


FIG. 3

1000. Nelson describes several examples of reactors that can be used for the in-flight reaction in a gas stream between promoter (Br_2 and/or HBr) and particulate sorbent material (powdered activated carbon, PAC) in order to produce the promoted brominated sorbent with an in-flight reaction:

> Note that the bromination step 4 can occur in any number of possible reactors. The particular equipment used to contact the carbonaceous substrates with the bromine-containing gas can be, for example, a stationary mixer, a rotating drum, a structure with a vertically-moving bed, a fluidized-bed unit, a transport reactor, or any other contactor known in the art. The manufacturing process is not limited by the type of process equipment used. Any equipment or method that quickly and evenly distributes the

> bromine-containing gas to intimately contact the carbonaceous particles will satisfy the requirements of the invention.[1437]

1001. Nelson discloses in-flight bromination of PAC in the gas phase by explicitly including fluidized beds and transport reactors as suitable means to brominate PAC, since both systems generate suspensions of PAC in gas mixtures that contain a bromine compound and thereby sustain spontaneous bromination of PAC. In both fluidized-bed reactors and transport reactors, the bromine gas and PAC are injected separately into a gas stream—bromine gas is fed into the bottom through a distributor plate or injected directly into the bed, whereas PAC is fed from a higher elevation to fall into the bubbling or dense bottom bed sections.

1002. A person of skill in the art would have understood that in fluidized-bed reactors, such as those disclosed in Nelson, a gas mixture is introduced through a distributor at the bottom of the bed that, first, suspends PAC and other solids in a bubbling bed section and, then, transports elutriated solids out of the bubbling bed into and through a riser section. The bromine compound can be fed upstream of the distributor or injected separately into the bubbling bed. The PAC is fed into the top of the bubbling bed section, where it settles into the bed emulsion in intimate contact with the gas mixture.[1438] The bromine-laden gas mixture contacts both the suspended

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1437 Ex. 1012 (Nelson) at 8:57-67.

1438 Ex. 1027 (Steam) at 16-1.

and elutriated PAC and brominates it until it is recovered in a particle collection device downstream of the riser outlet.

1003. A person of skill in the art would have also understood that in transport reactors, such as those disclosed in Nelson, the feeding configuration for the gas mixture and PAC particles are similar, but the gas flowrates are faster, and thereby operate in the "fast bubble" hydrodynamic regime, in which open channels penetrate a small and extremely dense emulsion phase that holds the PAC. Elutriated particles are again moved along a riser while their bromination continues in-flight.

272. I also note that the '147 patent employs a similar reactor as Nelson for the in-flight reaction of bromine and activated carbon:

- "an ebulliated or fluidized bed of base activated carbon, through which halogen/halide flows in gaseous form or as a vapor."[1439]
- "The halide/halogen gas, for example, gaseous HBr or Br_2, may be passed through an ebulliated or fluidized bed of granular or fibrous activated carbon, with the promoted carbon sorbent so produced removed from the top of the bed via gas entrainment for injection."[1440]

1004. Alternatively, I understand that Plaintiffs have contended that supplying of a bromide compound that might later change in the combustion system to a gaseous species such as HBr meets the claim limitations of Claim elements 17(a)-17(c). Plaintiffs contend that the scope of claim 17 encompasses the situation in which the

1439 Ex. 1001 ('147 Patent) at 9:61-64.
1440 Ex. 1001 ('147 Patent) at 10:28-33.

bromine-containing ingredients that were added to the coal or supplied to the combustion chamber vaporize and are converted to a promoter. While I do not agree that this arrangement meets a plain reading of claim 17, such a system is disclosed in Lissianski-Patent. Lissianski-Patent teaches supplying aqueous NH_4Br into Hg containing flue gas. A POSITA would have recognized that NH_4Br was highly soluble in water, such that in aqueous solution, the ammonium bromide would have been present as NH_4 cations and Br^- anions.

1005. Lissianski-Patent discloses introducing the NH_4Br solution into mercury-containing gas at a temperature of 1600-2000 °F.[1441] At this temperature, the water in the spray droplets simply evaporates to release the Br species into the Hg containing gas with a gas-phase "Br" concentration of 0.3 or 3 ppm.[1442]

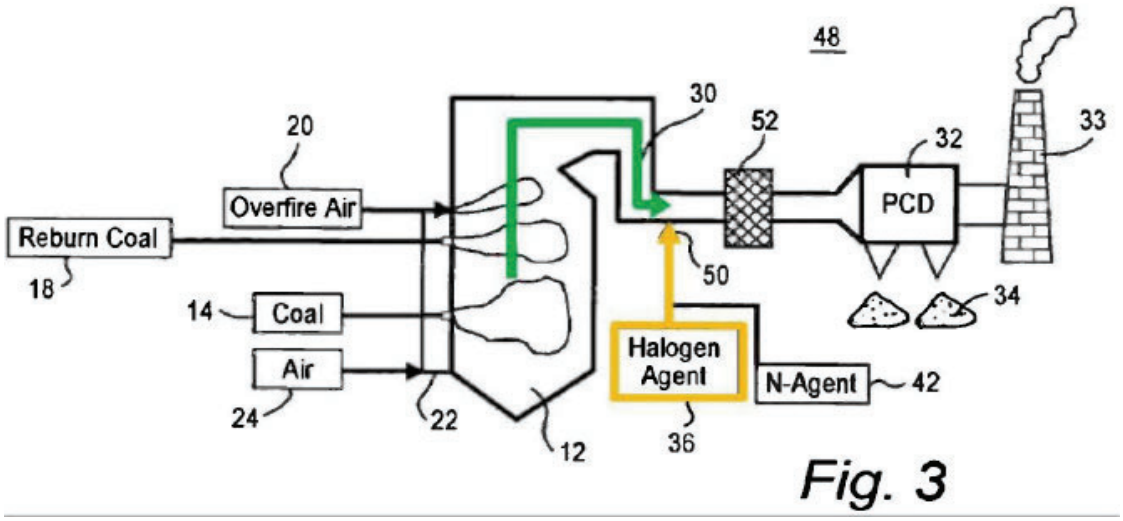
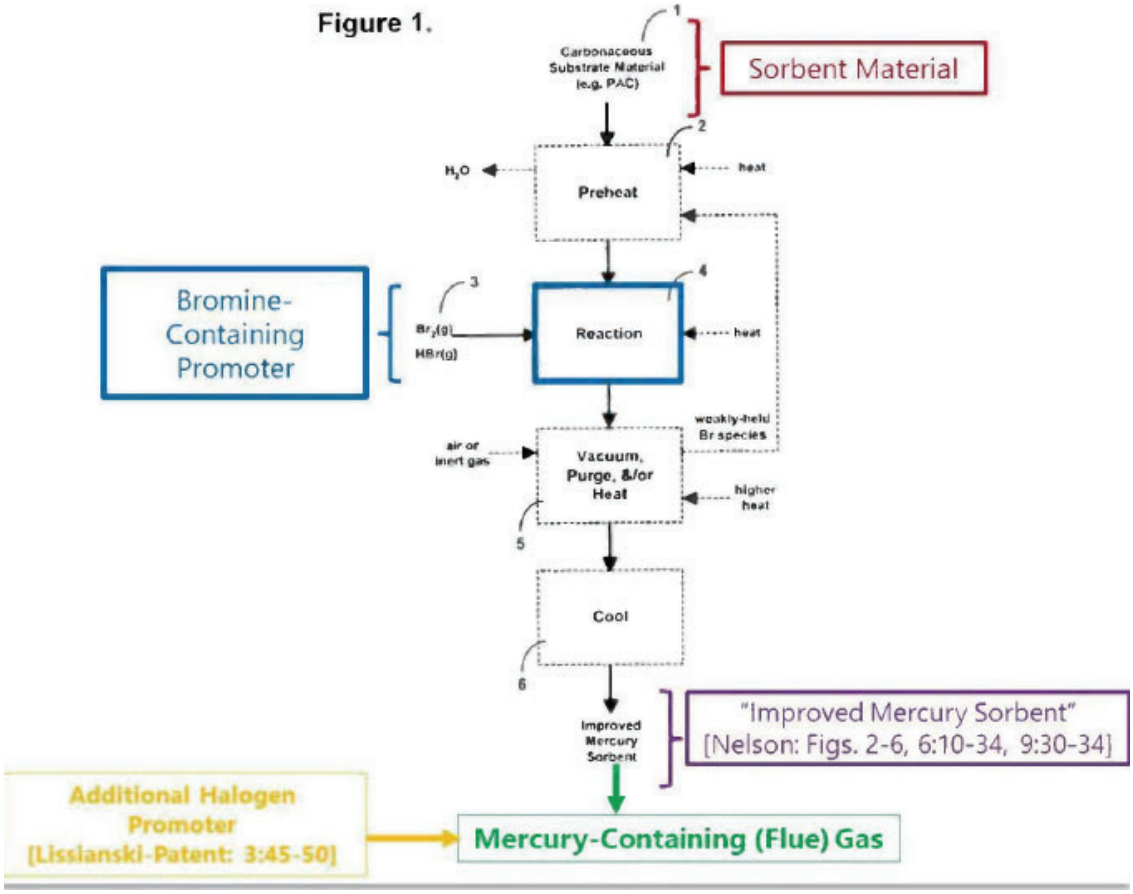


Fig. 3

1441 Ex. 1036 (Lissianski-Patent) at Abstract, 2:7-10, 3:51-57.

1442 Ex. 1036 (Lissianski-Patent) at 6:57-7:6, Fig. 9.

1006. Lissianski-Patent discloses that, in the hot flue gas, the NH_4BR additive will thermally decompose to form HBr.[1443] The HBr of Lissianski-Patent further reacts in the flue gas with the improved mercury sorbent of Nelson, as shown below:



1007. Under Plaintiffs' theory of infringement, a POSITA would have recognized that the Br-containing species in Lissianski-Patent would have been supplied "separately" from the pre-brominated sorbent of Nelson. For example, HBr is formed at "flue gas temperatures in a range of 1600°F … to 2300 °F,"[1444] with an

1443 Ex. 1036 (Lissianski-Patent) at Abstract, 3:42-50.
1444 Ex. 1036 (Lissianski-Patent) at 3:51-58.

optimal introduction temperature of approximately 1800°F.[1445] Further downstream, at the temperatures disclosed by Nelson for injecting sorbent (150°C), the Br-species would have remained in the gas phase when reacting with activated carbon, which promotes these carbons for both Hg^0 oxidation and capture of both Hg^0 and Hg(II). A person of skill in the art would have understood that the activated carbon would have been injected at a later (cooler) point in the mercury-containing flue gas, because a temperature of 1600-2000°F is above the flash point of activated carbon, and would combust the activated carbon (making it unavailable to adsorb anything). Indeed, Nelson discloses injecting the activated carbon at a cooler point in the flue gas, downstream of an air-preheater around 150°C (approximately 300°F).[1446]

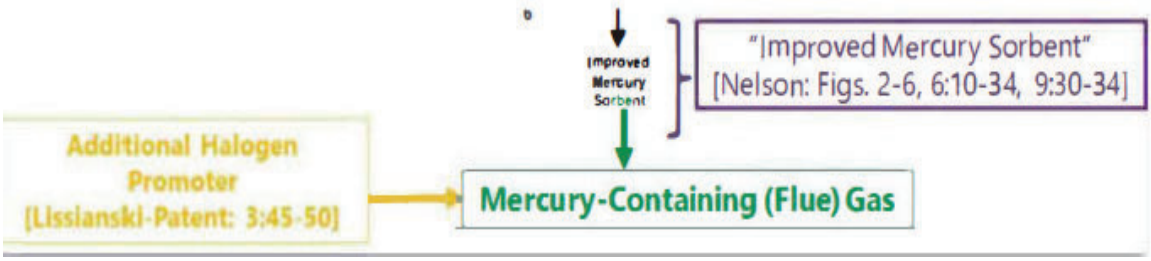
1008. A POSITA would have understood that an in-flight reaction, as required by Claim Element 17(b), would occur between the HBr of Lissianski-Patent added to the mercury-containing flue gas, and the previously (partially) promoted activated carbon of Nelson. With regard to Claim Element 17(c), I understand that Plaintiffs contend that the scope of claim 17 encompasses the situation in which the bromine-containing ingredients that were added to the coal or supplied to the combustion chamber vaporize and are converted to a promoter. Patent Owner contends that this vaporized bromine "is in gaseous form when it comes into contact with activated

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1445 Ex. 1036 (Lissianski-Patent) at Fig. 7.

1446 Ex. 1012 (Nelson) at 8:9-21, 9:21-28 (injection temperature of Figure 2), 13:30-32, 18:4-7.

carbon," in other words when the bromine-containing promoter flows as part of the flue gas.



1009. As described above regarding claim 1, a POSITA would have understood that HBr(g) chemically reacts with and promotes activated carbon to form a promoted brominated sorbent. Much like "gaseous hydrogen bromide, HBr(g)" was used to manufacture the improved mercury sorbent in Nelson,[1447] Lissianski-Patent discloses using the same gaseous HBr(g) to further promote the improved sorbent, thus meeting Claim Element 17(c).[1448] Also, the HBr(g) provided by Lissianski-Patent (orange, above) would have been available to react with the sorbent of Nelson (purple), and would not have been completely consumed in oxidizing mercury. The gas-phase Br concentration is 300-3000 times greater than the gas-phase mercury concentration (0.3-3 parts per million v. 10 parts per billion).[1449]

d. **<u>Claim 17: Element 17(d)</u>—"wherein the promoter is added at from about 1 to about 30 grams per 100 grams of the sorbent material."**

1447 Ex. 1012 (Nelson) at 6:10-13; *see also* 14:50.
1448 Ex. 1036 (Lissianski-Patent) at 3:41-49.
1449 Ex. 1036 (Lissianski-Patent) at 6:33-40, 6:62-67.

1010. Claim Element 17(d) states that the "promoter is added at ... ," but does not state where the promoter is added. In particular, Claim Element 17(d) does not specify whether: (i) the "promoter is added [to the sorbent] at from about 1 to about 30 grams per 100 grams," or (ii) the "promoter is added [to a gas stream] at from about 1 to about 30 grams per 100 grams." Claim Element 17(d) is obvious over Nelson in view of Olson and/or Lissianski-Patent under either interpretation.

1011. Nelson expressly describes the first interpretation: that the promoter is added *to the sorbent* at from about 1 to about 30 grams per 100 grams of sorbent. Nelson describes a ratio that is the same range, 1-30%, as that of this limitation:

> Any level of bromination of carbonaceous substrates appears to increase their mercury-removal performance. While over 30 wt % of Br_2 (g) can be adsorbed into some powdered activated carbons, for example, significant increases in mercury reactivity will be observed with only about 1 wt % Br_2 (g) in the PAC. Greater degrees of bromination do correlate with greater maximum mercury capacities for a particular carbonaceous sub strate.[1450]

1012. Nelson discloses in other places ratios of promoter added to sorbent within the claimed range:

> The gas-phase bromine treatment of this invention has been tested on many different commercially-available powdered activated carbons (PACs). Each has been found to be easily brominated to at least 15 wt % Br, including PACs from ... Norit. Norit's Darco FGDO is a common PAC frequently used by other researchers as a comparative yardstick.[1451] In this example, a

[1450] Ex. 1012 (Nelson) at 8:35-42.

[1451] Ex. 1012 (Nelson) at 11:11-19.

> Norit Darco FGD PAC was brominated according to the invention to 10 wt % with Br_2(g).[1452]

1013. Nelson further includes a table showing the "Final Loading on FGD PAC (wt %)," including bromination within the 1-30% weight ratio:[1453]

Gaseous Halogen	Final Loading on FGD PAC (wt %)	Adsorption Rate (gm of gas) / (kg PAC×min)	Concentration in Storage Vessel (ppm)
Br_2 (g)	5%	10	0
Br_2 (g)	15%	10	0.5
HBr (g)	9%	1	N.A.
Cl_2 (g)	13%	0.1	>40

1014. Figures 7-15 of Nelson all include bromine promoter added from about 5-22 grams per 100 grams of sorbent, which falls within the range recited in claim 17.[1454]

1015. As for the second interpretation, although Nelson does not expressly state the ratios of concentration in the gas-phase of HBr to activated carbon, or Br_2 to activated carbon, it would have been obvious to a person of skill in the art that the ratio of bromine-containing promoter to sorbent in the gas stream would have been similar the ratio on the sorbent. For example, Nelson discloses that the reaction

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1452 Ex. 1012 (Nelson) at 12:9-10; see also Ex. 1012 (Nelson) at 13:23-26 (Example 4, "15 wt% brominated sorbent of this invention"), 15:35-39 (Example 7, "PACS brominated with Br_2 to 5 wt % and 15 wt %, and with HBr to 9 wt %"); 15:42-46 (Example 8, "15 wt%-brominated sorbent").

1453 Ex. 1012 (Nelson) at 14:55-63.

1454 Ex. 1012 (Nelson) at Figs. 7-15.

between activated carbon and bromine-containing promoter takes place at 150 °C.[1455] A POSITA would have understood that at such a temperature, and given the highly reactive nature of HBr and Br_2 towards activated carbon, the promotion of activated carbon would have taken place spontaneously. Indeed, Nelson describes that the bromine-containing promoter is strongly held to the sorbent, such that even after storage "for a few days," there was a concentration of 0 ppm promoter that had desorbed from the sorbent when brominated to 5 wt % (using Br_2) and 9 wt % (using HBr).[1456]

1016. Lissianski-Patent discloses supplying promoter into the mercury-containing gas to provide bromine concentrations in the flue gas of 0.3 ppm and 3 ppm (parts per million).[1457] Given that the improved mercury sorbent of Nelson was already loaded with 1 - 15% bromine (1.5 wt%, 5 wt %, 10 wt%, 15 wt% in Figure 14), a POSITA would have chosen the smaller value of 0.3 ppm bromine (instead of 3 ppm bromine), especially in view of Lissianski's teaching that "a presence of only 0.3 ppm of bromine in flue gas results almost in the same effect as 3 ppm of

[1455] Ex. 1012 (Nelson) at 8:14-18, 9:25-29, 13:30-32, 16:49-51, 18:5-7, 18:23-26.

[1456] Ex. 1012 (Nelson) at 14:55-15:3.

[1457] Ex. 1036 (Lissianski-Patent) at 6:62-67, Fig. 9.

chlorine."[1458] Nonetheless, whether a POSITA were to select 0.3 ppm or 3 ppm, the ratio would still be adding from about 1 to about 30 grams promoter (from Lissianski) per 100 grams of the sorbent material (from Nelson).

1017. In order to determine a ratio of bromine concentration in the mercury-containing gas (as per Lissianski-Patent) to sorbent in the flue gas (as per Nelson), the concentrations must have the same units. Converting between ppm (rate of Br addition, per Lissianski-Patent) and pounds/MMACF (sorbent injection rate, per Nelson) would have been routine to a POSITA. In this case, converting both values to a grams/MMACF basis is the most convenient for comparison, and requires the fewest assumptions (the only assumptions being the flue-gas pressure). Such a routine conversion of units would have involved such basic concepts as the ideal gas law (to convert concentrations between temperatures and pressures), which was taught in first semester undergraduate chemistry to a person of skill in the art. Such a unit conversion would have also involved basic engineering knowledge of a power-plant operation, such as a typical flue gas pressure. This would have been well-known to a POSITA.

1018. A POSITA would have understood from the ideal gas law that the density of a gas is proportional to pressure and inversely proportional to temperature.

[1458] Ex. 1036 (Lissianski) at 6:62-67.

A POSITA would also have known that a typical flue gas temperature where sorbent would be injected is 150 °C (423 K) and also 1 atm of pressure. Indeed, Nelson teaches 150 °C as the injection temperature for the sorbent,[1459] and Lissianski-Patent discloses this temperature.[1460] Last, a POSITA would have found in readily available tables of unit conversions and/or basic chemistry books the following constants:

- 1 Actual Cubic Feet (ACF) = 1 ft^3 = 28.3168 L.
- 1 MMACF = 10^6 ACF
- Universal gas constant (R) = 0.082058 (L*atm) / (mol*K)
- Molecular weight of Br = 79.904 g/mol

273. Based on the above constants and relationships, the concentration of active-carbon sorbent in the flue gas from Nelson can be calculated as:

$$\frac{3.7\ pounds\ PAC}{MACF} \times \frac{453.592\ grams}{pound} = 1{,}678.29\ \frac{grams\ Activated\ Carbon}{MACF}$$

Based on the above constants and relationships, the concentration of HBr in the flue gas can be calculated as follows:

$$\frac{0.3\ \text{mol HBr}}{10^6\ mol\ flue\ gas} \times \left(\frac{79.904\ \text{g Br}}{1\ \text{mol Br}}\right) = 2.4 \times 10^{-5}\ \frac{g\ Br}{mol\ flue\ gas}$$

A POSITA would have readily been able to convert the flue gas from a molar basis (mol) to a volumetric basis (ACF) as follows:

[1459] Ex. 1012 (Nelson) at 8:14-18, 9:25-30, 13:30-32, 16:49-51, 18:1-7, 18:23-26.

[1460] Ex. 1036 (Lissianski-Patent) at Fig. 9.

$$\frac{ACF\ flue\ gas}{mol\ flue\ gas} = \frac{(423\ k) \times \left(0.082058\ \frac{Latm}{mol\ K}\right) \times \frac{ACF}{28.3L}}{1\ atm} = \frac{1.226\ ACF\ flue\ gas}{mol\ flue\ gas}$$

Combining the above equations to calculate the grams HBr per MACF flue gas:

$$2.39\ \times\ 10^{-5}\ \frac{g\ Br}{mol\ flue\ gas} \times \frac{1\ mol\ flue\ gas}{1.226\ ACF} \times \frac{10^{6} ACF}{MACF} = 19.5 \frac{g\ Br}{MACF}$$

274. Thus, when comparing the application rate of the additional bromine promoter described by Lissianski-Patent (0.3 ppm, or 19.55 g / MACF), and the injection rate of the sorbent described by Nelson (1,678 g / MACF), there is 1.17 grams of bromine-containing-promoter added to the gas stream per 100 grams of activated carbon. And using the higher number disclosed in Lissianski-Patent for the bromine-addition rate (3 ppm), the ratio would be 11.7 grams of bromine-containing promoter added to the mercury-containing gas per 100 grams of activated carbon. Each of these numbers are within the range of adding promoter from about 1 to about 30 grams per 100 grams of the sorbent material.

1019. I also note that Claim Element 17(d) is merely an attempt to claim a workable range for combining a conventional halogen (bromine) being used in a conventional way (to promote activated carbon) with a conventional sorbent (activated carbon). Nothing in the '147 patent specification attributes significance to the claimed range or establishes that the claimed range achieves unexpected results. The range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA. Through routine process optimization and

routine experimentation, a POSITA would have adjusted the rate of addition of the promoter and/or the rate of addition of the sorbent material to achieve a range from about 1 g to about 30 g of promoter per 100 grams of the sorbent material, under either interpretation of Claim Element 17(d) to achieve more-optimum application of promoter and sorbent, from the standpoint of maximizing the marginal-benefit. Moreover, the range is approximate, as claim 17 recites "from *about* 1 to *about* 30" for the ratio and indicates in the specification that less than 1 gram of bromine may be taken up by 100 g of activated carbon.[1461] The range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA.

2. Claim 18. "A method according to claim 17, wherein the gas stream is a mercury containing gas."

1020. Regarding Claim 18, as I have described throughout this section, the additional promoter of Lissianski-Patent and the pre-brominated sorbent of Nelson react in-flight with one another in a mercury-containing (flue) gas.

3. Claim 19. "A method according to claim 18, wherein the gas stream is a transport gas."

1021. I understand that Plaintiffs have alleged that any gas that is being transported is a transport gas. Under this theory, the mercury containing gas of

[1461] Ex. 1001 ('147 Patent) at claim 17 (emphasis added), 19:64-67 ("The amount of bromine taken up by the carbon ranges (in one example) from <1 to about 30 g per 100 g of activated carbon, depending on the proportions used.").

Nelson or Lissianski Patent qualify as transport gas. Figure 1 of Nelson, for example, show the gas being transported in a stream through the figure.

1022. Lissianski-Patent states that additional bromine-containing promoter can be introduced by using "air, recycled flue gas, nitrogen or another carrier gas" in order to improve mixing.[1462] In combination with Nelson, the mercury-containing flue gas is a transport gas, which transports the additional bromine-containing promoter of Lissianski-Patent to the improved mercury sorbent of Nelson.

1023. Lissianski-Patent describes supplying the additional bromine-containing promoter to a mercury-containing flue gas.[1463] Lissianski-Patent also describes that the flue gas flows downstream, such as to an SCR unit or particulate collection devices:[1464] A POSITA would have recognized that as the mercury-containing flue gas flows downstream, the entrained additional bromine-containing promoter (e.g., HBr) flows with the flue gas and is transported by it. As described in the Reasons to Combine and for claims 17-18, it would have been obvious to a POSITA that the additional bromine-containing promoter of Lissianski-Patent would have been introduced upstream of the improved mercury sorbent of Nelson. That promoter

[1462] Ex. 1036 (Lissianski-Patent) at 4:20-23; *see also* claim 24 ("air, *recycled flue gas* and nitrogen gas").

[1463] Ex. 1036 (Lissianski-Patent) at 3:42-48.

[1464] Ex. 1036 (Lissianski-Patent) at 4:14-59, Figs. 1-3.

would be transported with the mercury-containing flue gas downstream to the improved mercury sorbent of Nelson.

4. Claim 20. "A method according to claim 17, wherein the promoter injection rate and the sorbent injection rate into the gas are determined at least in part on the monitored mercury content of the cleaned gas."

1024. The limitations added in Claim 20 are obvious in light of Nelson. Claim 20 recites "the cleaned gas," but does not expressly state which "cleaned gas" is being referenced. Claim 20 will be analyzed as if "the cleaned gas" were to mean a gas from which particulates including ash and the mercury/sorbent chemical composition has been separated, pursuant to Claim Element 1(c).

1025. The limitations added in Claim 20 are obvious in light of Nelson. Nelson discloses an analyzer for monitoring gas-phase mercury content.[1465] In particular, continuous mercury monitors ("CEMs") are used to measure mercury concentrations of the cleaned gas:

> In these trials, the mercury was measured using a speciating PS Analytical Sir Galahad continuous mercury monitor. Inlet mercury values were obtained by sampling upstream of the sorbent injection point and outlet mercury was measured at the stack.[1466]

1026. The "outlet mercury was measured at the stack" refers to measuring the mercury content of the cleaned gas. Nelson explains that throughout the figures,

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[1465] Ex. 1012 (Nelson) at 11:50-56, 13:63-67.

[1466] Ex. 1012 (Nelson) at 15:14-17.

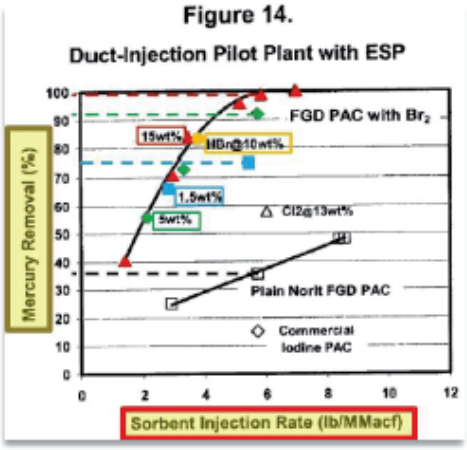
"Mercury levels both into and out from the materials were measured with a gas-phase elemental mercury analyzer."[1467] Again, the "out from the materials" in Nelson refers to monitoring the mercury content of the cleaned gas. I also note that Nelson and the '147 patent disclose the same manufacturer and model of mercury monitor-a Sir Galahad monitor from P.S. Analytical.[1468]

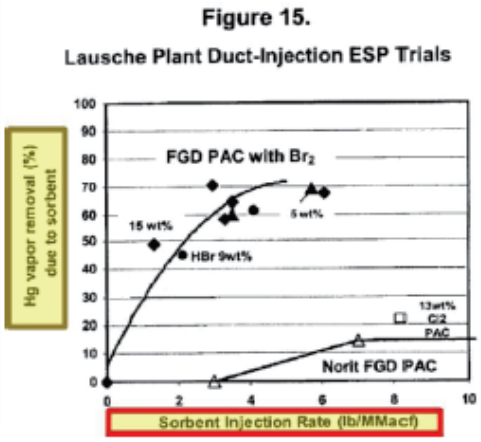
1027. Nelson further provides small-scale and commercial-scale test data, as evidenced by Figures 14 and 15, respectively, that increasing the total bromine added to the system reduces mercury concentration in the flue gas. Figure 14 simulates the mercury capture in a coal-fired plant at small scale, and Figure 15 "indicates the mercury capture capabilities in an actual coal-fired" plant.[1469]' In these figures, Nelson discloses that the monitored mercury content (Y-axis) of the cleaned gas depends on: (i) "injection rate" of promoted sorbent (X-axis); and (ii) composition of the promoted sorbent (as represented by the different data sets, such as 1.5%, 5%, 10%, and 15%).

1467 Ex. 1012 (Nelson) at 11:50-52.

1468 Ex. 1012 (Nelson) at 15:14-17; Ex. 1001 ('147 Patent) at 15:30-32, 19:37-40.

1469 Ex. 1012 (Nelson) at 5:51-59.





Mercury content of the cleaned gas was measured using a "continuous mercury monitor."[1470] Nelson discloses the same manufacturer and model of mercury monitor as the '147 patent.'[1471]

1028. Based on Figures 14-15 of Nelson, it would have been obvious to determine a desired sorbent-injection rate and a sorbent composition "at least in part on the monitored mercury content." For example, if measured mercury content in the cleaned gas were too high when using sorbent with 5 wt% bromine, it would have been obvious to either increase the sorbent-injection rate (X-axis) or use a sorbent composition with a different amount of bromine (e.g., 15 wt% bromine). A POSITA would have known that the sorbent composition of Figures 14-15 depends on the promoter injection rate used to manufacture that promoted sorbent off-site.

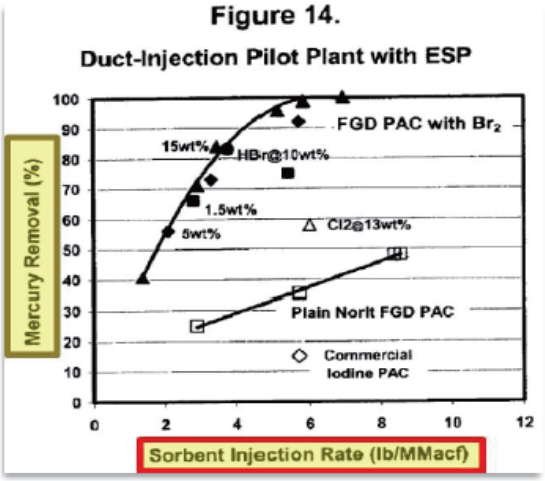
1470 Ex. 1012 (Nelson) at 11:50-56, 13:63-67.

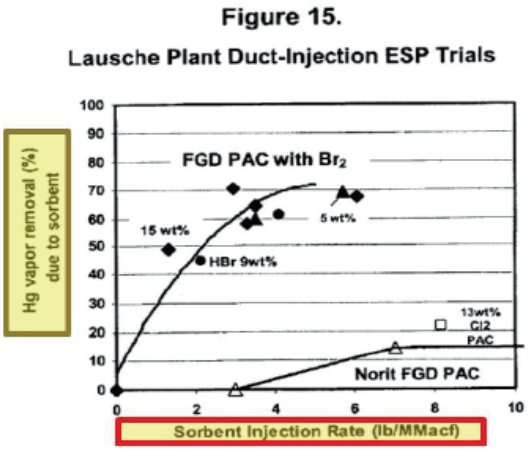
1471 Ex. 1012 (Nelson) at 15:14-17; Ex. 1001 ('147 Patent) at 15:30-32, 19:37-40.

Ex[1012], Fig. 1. For example, Claim 20 does not require that sorbent and promoter injection rates "are determined" at the same time. Nor does it require continuously monitoring mercury content, continuously adjusting sorbent injection rate and promoter injection rate, or sending or receiving control feedback signals. As such, it would have been obvious to determine the promoter injection rate "at least in part on the monitored mercury content." Further, it was well-known in the art, and discussed by EPA, that when using halogens with activated-carbon sorbent, "the amount of sorbent needed" and "the amount of Cl [halogen] present" are two primary variables to control mercury removal.[1472]

1029. In addition to the reasons provided in Ground 1, Claim 20 is also obvious over Nelson in view of Olson-Paper and Lissianski-Patent. As discussed for Claims 17-18 (Ground 2), the promoted sorbent of Nelson is a "sorbent." Figures 14-15 of Nelson disclose that monitored-mercury content of cleaned gas (brown, Y-axis) depends on "sorbent injection rate" of promoted sorbent (red, X-axis).

[1472] Ex. 1009 (EPA-Proposal) at 4676.





1030. Based on Figures 14-15, it would have been obvious to determine a desired sorbent-injection rate "at least in part on the monitored mercury content"—measuring mercury and determining which "sorbent injection rate" to use. A POSITA would have also found it obvious to determine the injection rate of an additional halogen-containing promoter (as disclosed by Lissianski-Patent) at least in part on the monitored-mercury content.